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IS 13805 (2004): General Standard for Qualification and Certification of Non-Destructive Testing Personnel [MTD 21: Non-Destructive Testing]

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(पहला पुनरीक्षण)

Indian Standard

GENERAL STANDARD FOR QUALIFICATION AND CERTIFICATION OF NON-DESTRUCTIVE TESTING PERSONNEL — SPECIFICATION

(First Revision)

ICS 03.100.30; 19.100

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BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

August 2004 **Price Group 17**

AMENDMENT NO. 1 DECEMBER 2010
TO
IS 13805 : 2004 GENERAL STANDARD FOR QUALIFICATION AND CERTIFICATION OF NON-DESTRUCTIVE TESTING PERSONNEL — SPECIFICATION

(First Revision)

(*Page* 13, *clause* **8.4**) — Substitute the following for the existing:

‘**8.4 Renewal**

8.4.1 After the period of validity, certification may be renewed by the National Certifying Body, directly or through an authorized qualifying body, for an additional period of five years from the date of expiry provided the individual meets the following criteria:

a) Provides evidence of satisfactory visual examination, and

b) Provides evidence of continued satisfactory work activity without significant interruption.

Applications for renewal can be made up to 6 months before the date of expiry. Up to 6 months after the certificate expiry date, a candidate’s certification status can be reactivated.’

(*Page* 13, *clause* **8.4.2**) — Delete.

(*Page* 13, *clause* **8.5**) — Renumber the clause as **8.6**.

(*Page* 14, *clause* **8.6**) — Renumber the clause as **8.5** and substitute the following for the existing:

8.5 Recertification

8.5.1 *General*

In case the candidate fails to renew his existing certificates, to regain certification for that method (and sector), the candidate shall be required to apply for fresh certification and has to undergo the appropriate method of examination (general and specific) including practicals in the case of Level I and II.

Prior to completion of each second period of validity, or at least every ten years, the certified individual may be recertified by the certification body for a similar period, provided the individual meets the criterion in **8.4** for renewal and meets the following conditions, as applicable.

8.5.2 *Level I and II*

The individual shall successfully complete a practical examination that assesses ongoing competence to carry out within the scope of the certificate, according to the following:

a) *See* Table 8 for guidance on the subjects to be covered and their percentile weighting in the practical examination. If the individual fails to achieve a grade of at least 70 percent for each specimen tested, two retests of the recertification examination shall be allowed within 12 months of the first attempt at the recertification examination; and

b) In the event of failure in the two allowable retests, the individual shall not be recertified and, in order to regain certification for that level, sector and methods, the individual shall apply for new certification. If the individual holds valid certification in a different sector of the same method, an exemption in the general examination will be allowed.

8.5.3 *Level III*

In the case of Level III personnel recertification by Indian Society for Non-destructive Testing is intended to apply only to individuals who maintain continued active employment in NDT Level III functions and demonstrate efforts to keep abreast of the technology in the method(s) for which recertification is sought.

Recertification can be obtained by application subject to the following conditions:

a) Reaffirmation of the ‘Code of Ethics’ for Level III Non-destructive Testing Personnel certified by ISNT and as prescribed in the NCB Quality Manual;
b) Continued active employment in Level III functions as related to the NDT Method(s) for which recertification is sought;

c) Such employment must have covered at least 36 months during the valid certification period but not necessarily 36 consecutive months;

d) At least 12 of the 24 months immediately preceding the expiration of the certification must have been spent in Level III functions; and

e) If work experience during the certification period did not include all methods for which recertification is sought, at least two additional points shall be obtained in each method for which there was no work experience.

The demonstration of an effort to keep up-to-date, contribute to knowledge or maintain continued growth in the method(s) for which the individual is certified or to expand knowledge in related technologies by obtaining a minimum number of points during each 5 year period of certification as given in Table 11.

To be recertified, it is necessary to gain a minimum of 30 points in a 5 year period. A maximum of 10 points per year will be allowed.

(*Page* 14, *Table* 11) — Add reference to clause **8.5.3**.

(*Page* 15, *Annex* A) — Add the following matter after the table:

Basic Examination Level III

This Basic Examination will cover three (3) main areas:

1.1 Personal Qualification and Certification

The NDT Personnel should have knowledge of certification body’s qualification and certification system based on this Standard (IS 13805).

1.2 General Knowledge of Materials, Fabrication Processes and Product Technology

1.3 Fundamentals of Material Technology

a) Structure of metals and alloys;
b) Physical and mechanical properties of metallic materials; and

- c) Behaviour of materials in service, Modes of failures:
  - i) Corrosion,
  - ii) Fatigue,
  - iii) Wear,
  - iv) Overload, and
  - v) Brittle fracture.

1.4 Fundamentals of Fabrication and Product Technology

- a) Metal processing — Castings, Mechanical working (Forging, Rolling, Extrusion, Drawing), Heat Treatment, Welding, Powder Metallurgy;
- b) Non-metals and composite materials processing; and
- c) Origin & Nature of Defects associated with each processing method.

1.5 Dimensional Metrology

Fundamental Units & Standards — Gauging — Interferometery

2.0 General Familiarity with the Following NDT Methods

NDT Methods	*Abbreviations*
Acoustic Emission Testing	AT
Electromagnetic Testing	ET
Penetrant Testing	PT
Leak Testing	LT
Magnetic Particle Testing	MT
Neutron Radiographic Testing	NRT
Radiographic Testing	RT
Infrared/Thermal Testing	IRT
Ultrasonic Testing	UT
Vibration Analysis Testing	VAT
Visual Testing	VT

Fundamentals – Principles/Theory – Sensors/Sources – Equipment and Material – Techniques – Detection – Electronics/Instrumentation – Interpretation & Evaluation of Test Results – Codes and Standards – Safety – Documentation – Application

This is applicable to all the mentioned NDT methods.

(MTD 21)

Reprography Unit, BIS, New Delhi, India

Non-destructive Testing Sectional Committee, MTD 21

FOREWORD

This Indian Standard (First Revision) was adopted by the Bureau of Indian Standards, after the draft finalized by the Non-destructive Testing Sectional Committee had been approved by the Metallurgical Engineering Division Council.

The effectiveness of any application of non-destructive testing (NDT) depends upon the capabilities of the persons who are responsible for, and perform the test. This has been developed to provide a means for evaluating and documenting the competence of the personnel whose duties require adequate theoretical and practical knowledge of the NDT tests they perform witness, monitor or evaluate. Annex A and Annex B are integral part of this standard which have been separated for reasons of convenience.

Most of the fabrication and inspection codes insist that only qualified and certified personnel are employed to carry out mandatory NDT inspection jobs at various levels. Therefore it is the responsibility of the manufacturer and /or the employer to properly train and certify his NDT personnel.

This standard was first published in 1993 while reviewing this standard in the light of experience gained during these years, the Committee felt to revise this standard. While revising this standard international practices have been duly considered along with specific Indian scenario and accordingly it is essentially aligned with International Standard.

In this revision assistance has been derived from the following:

> ISO 9712 : 1999 'Non-destructive testing, qualification and certification of NDT personnel' issued by the International Organization for Standardization.
>
> ANSI/ASNT CP-189 1995 American national standard for qualification and certification of NDT personnel.
>
> EN 45013 : (1989) General criteria for certification bodies operating certification of personnel.
>
> Recommended practice No. SNT-TC-1A 1996, published by American Society for Non-Destructive Testing, USA.
>
> IAEA-TECDOC-628 (1991), Training guidelines in non-destructive testing techniques, published by the International Atomic Energy Agency (IAEA), Vienna, Austria.

Indian Standard

GENERAL STANDARD FOR QUALIFICATION AND CERTIFICATION OF NON-DESTRUCTIVE TESTING PERSONNEL — SPECIFICATION

(First Revision)

1 SCOPE

1.1 This standard establishes a system for the qualification and certification of personnel to perform industrial non-destructive testing using any of the following methods:

NDT Methods	*Abbreviations*
Acoustic emission testing	AT
Eddy current testing	ET
Liquid penetrant testing	PT
Leak testing	LT
Magnetic particle testing	MT
Neutron radiography testing	NRT
Radiographic testing	RT
Infrared testing	IRT
Ultrasonic testing	UT
Vibration analysis testing	VAT
Visual testing	VT

1.2 Atomic Energy Regulatory Board (AERB)

Atomic Energy Regulatory Board, constituted in 1983 by Government of India is the competent authority to authorize licensing, inspection and operation of equipments/facilities and personnel involving radioactive material. AERB through the authorized Division of Radiological Protection, Bhabha Atomic Research Centre, Mumbai certifies personnel for radiographic inspection and site-in-charge. Level I, II and III certification scheme in radiography is independent of AERB certification and does not cover licensing.

2 TERMINOLOGY

2.1 Authorization — A permission to work issued by the employer or responsible agency based on the individual's suitability for a specific job. In addition to the certification, amongst other's the job specific knowledge, skill and physical ability could be assessed.

2.2 Authorized Qualifying Body — Competent organization, independent of the employer or responsible agency, approved by the certification body to prepare and administer examinations to qualify NDT personnel.

2.3 Basic Examination — This is applicable for level III only. It includes written examination, covering basic knowledge of other NDT methods, various materials, manufacturing processes and service conditions, discontinuities, their characteristics and causes, destructive testing, metallurgy, materials testing, metrology, quality assurance, safety in NDT, etc.

2.4 Basic Education — Minimum formal academic education required for qualification. It may be used to determine duration and level of training and experience required to be eligible for certification in NDT.

2.5 Candidate — The individual seeking certification in accordance with this standard.

2.6 Certification — The procedures leading to a written testimony of the qualification of an individual's level of competence to perform the tasks associated with a given NDT method.

2.7 Certificate — Written testimony of qualification by Authorised Qualification Body as per the provisions of this standard.

2.8 Employer or Responsible Agency — The organization for which the candidate works on a regular basis. Candidate may be self-employed.

2.9 Experience — The period during which the candidate performed the specific NDT method as his main activity under qualified supervision including personal application of the NDT method to materials, parts or structures. It does not include practical performed during training courses.

2.10 Examination Centre — Centre approved by the national certificate body, either directly or through the authorized qualifying body, where qualification examination will be carried out.

2.11 Examiner — A person qualified to level III in the NDT method he is to examine and authorized by the certification body to conduct and/or grade NDT qualification examinations.

NOTE — No level III person shall be the examiner for any candidate he has personally trained for that examination.

2.12 General Examination — The general examination includes a written and a practical part for levels I and II and a written theory for level III. This written examination will be based on principles and application of applicable NDT method. In the practical examination for levels I and II, the candidate demonstrates the familiarity with and the ability to calibrate and operate the necessary test equipment, test the components and to record analyze and interpret the test results to the required code/standard/ specification.

2.13 Industrial Sector — A particular area in industry or technology where specialized NDT practices are utilized requiring specific skill, knowledge, equipment or training to achieve satisfactory performance. An industrial sector may be interpreted to mean a product (welds, castings, etc) or an industry (Aerospace, Steel, etc).

2.14 Job Specific Examination — Additional examination concerned with the application of NDT method to a particular specified product not commonly covered in general and specific examination; an examination which supplements this standard and is carried out following written guidelines with results recorded to meet quality assurance or customer audit requirements. For levels I and II this examination is outside the scope of this standard. It is normally to be administered by the employer. Level III specific examination include procedure writing and interpretation of code/specification and interpretation of test indications.

2.15 National Certifying Body — The agency that administers procedures for certification of NDT personnel according to the requirements of this standard.

2.16 NDT Training — A process of instruction in theory and practice in the NDT method in which the certification is being sought. This may take the form of training courses to an approved syllabus and periods of practical work under qualified supervision.

2.17 NDT Method — The discipline associated with applying a physical principle in non-destructive testing (for example, ultrasonic testing).

2.18 NDT Technique — A specific way of utilizing an NDT method (for example, immersion ultrasonic technique).

2.19 NDT Procedure — An orderly sequence of steps which describes in detailed terms where, how and in which sequence an NDT method should be applied to a product. It may include acceptance standards.

2.20 NDT Instruction — A written description detailing the precise steps to be followed in testing to an established NDT procedure, standard, code or specification.

2.21 Operating Authorization — Permission to work, issued by the employer or responsible agency and based on the individual's suitability for a specific job.

2.22 Qualifying Examination — An examination administered by the National Certifying Body or an authorized qualifying body, to assess the knowledge and capabilities of the candidate.

2.23 Qualification — A demonstration of the knowledge, skill, training and experience required to properly perform NDT tasks.

2.24 Specific Examination — The specific examination includes both a written and a practical part for levels I and II. The written test is concerned with components, systems, equipments, operating procedures and test techniques commonly used in a particular industrial sector. It involves the demonstration of knowledge related to product being tested and covers the applicable codes, specifications, standards, procedures used in the concerned method. During the specific written examination, the candidate shall be required as a minimum to give answers to number of questions as defined in Table 4. There will be multiple choice questions based on written procedure/technique sheets for level I and for level II. There also will be multiple choice questions based on codes/standards/specifications and their interpretations. The practical test of the specific examination is to verify the candidate's ability to perform testing of components/ products and also recording and analysis of the results to the degree required to the specific testing instructions/ specifications. For level III specific examination includes procedure writing and interpretation of code/specification and interpretation of test indications.

2.25 Significant Interruption — Absence or a change of activity which prevents the certified individual from practicing the duties corresponding to his level in the method and the industrial sector(s) for which he is certified, for a continuous period exceeding one year.

2.26 Supervision — Act of directing the application of NDT performed by other NDT personnel, which includes the control of actions involved in the preparation of the test, performance of the test and reporting of the results.

2.27 Test Specimen — Specimen used in practical examinations.

2.28 Trainee — An individual who works under the supervision of certified personnel but who does not conduct any tests independently, does not interpret test results and does not write reports of test results. He may be registered as being in the process of gaining appropriate experience to establish eligibility for qualification to level I or for direct access to level II and level III.

3 LEVELS OF COMPETENCE

3.1 Classification

An individual certified in accordance with this standard shall be classified in one of the three levels depending upon his respective level of competence. One who has not yet attained certification may be registered as a trainee.

3.2 NDT Level I

An individual certified to NDT level I is qualified to carry out NDT operations according to written instructions. He shall be able to set up the equipment, to carry out the tests, to record the results obtained, to classify the results in terms of written criteria; and to report the results. He shall receive the necessary instruction and/or supervision from level II or level III personnel. He shall not be responsible for the choice of the test method or technique to be used nor for the assessment of test results.

3.3 NDT Level II

An individual certified to NDT level II is qualified to perform and direct non-destructive testing according to established or recognized techniques. He shall be competent to choose the test techniques to be used, to set up and calibrate equipment, to interpret and evaluate results according to applicable codes, standards and specification, to carry out all duties for which a level I individual is qualified and to check that they are properly executed, to develop NDT procedures adopted to problems which are the subject of an NDT specification, and to prepare written instructions, organize and report the results of non-destructive tests. He shall also be familiar with the scope and limitations of the method for which he is qualified, and able to exercise assigned responsibility for on the job training and guidance of trainees and NDT level I personnel.

3.4 NDT Level III

An individual certified to NDT level III shall be capable of assuming full responsibility for a test facility and staff, establishing techniques and procedures, interpreting codes, standards, specifications and procedures to be used. He shall have the competence to interpret and evaluate results in terms of existing codes, standards and specifications, a sufficient practical background in applicable materials, fabrication and product technology to select methods and establish techniques and to assist in establishing acceptance criteria where no standard practices are otherwise available, general familiarity with other NDT methods, and the ability to guide and train level I and level II personnel.

4 GENERAL PRINICIPLES OFCERTIFICATION

4.1 Administration

The certification activity that includes all procedures adopted to demonstrate the qualification of an individual to carry out tasks in a specific NDT method and leads to a written testimony of his competence shall be administered by the National Certifying Body with the assistance, where necessary, of duly authorized qualifying bodies.

4.2 National Certifying Body (NCB)

The National Certifying Body shall be a non-profit body which may be formulated by Indian Society for Non-destructive Testing (National Governing Council) and approved by appropriate government ministry, if necessary.

4.2.1 *Composition*

The National Certifying Body shall include eminent representatives from academic institutes, research centre, industries, Government nodal ministries, public sector undertakings, private sector, other related societies or institutes, insurance bodies, third party inspection agencies including classification societies as appropriate. The NCB shall establish in writing the number of members in the body and their tenure. The body shall submit its report at least once in a year to the body forming authority.

4.2.2 *Responsibilities*

The National Certifying Body:

a) shall initiate, maintain and promote the national certification scheme according to this standard;
b) shall administer the procedures and operation for certification in accordance with the documents;
c) shall prescribe an obligatory code of ethics including options which shall apply to committee members and certificate holders;
d) may delegate, under its direct responsibility, the detailed administration of the certification procedure to other organizations which will act as qualifying bodies and which could represent industrial sectors;
e) shall take the ultimate responsibility for the certification scheme including technical and administrative requirement;
f) shall approve, either directly or through a qualifying body, properly staffed and equipped examination centres, which it shall monitor on a periodic basis;
g) shall keep all appropriate records and issue or delegate the issuing of the written testimonies;
h) shall identify the examiners to start the scheme;
j) shall approve training agencies in NDT methods;
k) shall prepare and updated question bank for examinations and also maintain the set of practical examination; and
m) shall develop and maintain a quality manual which

shall outline the quality policy and objectives of NCB and also detail/document the procedures methodologies including implementation.

4.3 Authorized Qualifying Bodies

An authorized qualifying body shall, where established be approved by the certification body and shall, with the approval of the certification body:

a) apply a documented quality procedure outlined in quality manual of National Certifying Body;
b) establish and monitor examination centres;
c) prepare and supervise the qualification examinations; and
d) maintain appropriate qualification and examination records according to the requirements of the certification body.

4.4 Employer or Responsible Agency

Employer or responsible agency shall introduce the candidate to the National Certifying body and document the validity of the personal information provided including the declaration of education, training and experience used to establish eligibility of the candidate, but shall not be directly involved in the certification procedure itself.

The employer or responsible agency shall be fully responsible for all that concerns the authorization to operate and the validity of the results of NDT operations. The employer shall also ensure that the annual vision acuity requirements of **5.4** are met and verify the continuity in the application of the NDT method without significant interruption.

NOTE — If the individual is self employed, he shall assume all responsibilities described for the employer or responsible agency, and shall be required to provide additional documentation to support claims for experience and training.

4.5 Examination Centres

4.5.1 Examination centres approved by the National Certifying Body or through authorized qualifying bodies shall have following minimum requirements:

a) have adequate qualified staff, premises and equipment as decided by National Certifying Body to ensure satisfactory qualification examinations for the levels, methods, and industrial sectors concerned;
b) use only those documents and examination questionnaires established or approved by the National Certifying Body; and
c) use only specimens prepared or approved by the National Certifying Body for the practical examinations conducted at that centre. Apply a documented quality procedure outlined in quality manual.

NOTE — When more than one authorized examination centre exists, each should have specimens containing comparable defects. The examination specimens shall not be used for training purpose under any circumstances.

4.5.2 An examination centre can be situated at employer's premises. In this case, examinations shall be conducted only in the presence of and under the control of an authorised representative of the certification body.

5 ELIGIBILITY FOR EXAMINATION

5.1 General

To be eligible for examination, the candidate shall fulfill and provide documented evidence acceptable to the certification body regarding the minimum education, NDT experience and training requirements which are specified in this clause.

5.2 Education and Experience

To be eligible for certification, the candidates shall have the minimum educational qualifications in combination with experience as indicated in Tables 1 and 2.

NOTE — In case a candidate is appearing for more than one method credit for work experience may be gained simultaneously in two or more of the NDT methods covered by the standard, with the reduction of total required practical experience as follows:

a) Two testing methods — reduction of total required time by 25 percent, and
b) Three or more testing methods — reduction of total required time by 33 percent.

The candidate shall be required to show that, for each of the testing methods for which he seeks certification, he has at least 25 percent of the time required in Tables 1 and 2. In case he works less than half the time in a particular method, experience requirements will be proportionally higher, for example, if he is working only 10 percent of the time, experience requirement will be five times.

5.3 Training : Levels — I, II and III

5.3.1 To be the eligible to apply for certification in an NDT method, the candidate shall provide evidence of satisfactory completion of a training programme conducted by an agency duly approved by NCB in that methods given in Table 3.

5.3.2 The minimum duration of the training to be undertaken by the candidate for certification shall be as defined in Table 3 for the applicable NDT method.

5.3.3 Time for examination not included in Table 3.

5.3.4 For level III, training in basic is common to all the methods. If a candidate has taken this training, he does not have to repeat this training for adding the methods.

Table 1 Minimum Experience Requirements — Level I and Level II

(*Clause* 5.2)

NDT Method		Experience Months 1) 2) 3) 4) 5) 6)	
		Level I	Level II 2)
(1)		(2)	(3)
AT		6	12
ET		3	9
IRT		3	18
LT	Total experience	4	9
	a) Bubble test (BT)	1	1
	b) Pressure change test (PCT)	2	4
	c) Halogen diode leak test (HDLT)	2	4
	d) Mass spectrometer leak test (MSLT)	4	6
MT		1	3
NRT		6	24
PT		1	3
RT		3	18
UT		3	18
VAT		6	24
VT		1	3

1) Work experience in months is based on a nominal 40 h/week or the legal week of work. When an individual is working in excess of 40 h per week, he may be credited with experience based on the total hours, but he/she is required to produce evidence of this experience.

2) If the individual is being qualified directly to level II, with no time at level I, the experience shall consist of the sum of the times required for level I and level II.

3) Experience duration may be reduced by up to 50 percent but shall not be less than one month when the certification sought is limited in application (for example, automated testing).

4) Credit for work experience may be gained simultaneously in two or more of the NDT methods covered by this standard, with the reduction of total required experience as follows:

Two testing methods — reduction of total required time by 25 percent.

Three testing methods — reduction of total required time by 33 percent.

Four or more testing methods — reduction of total required time by 50 percent.

In all cases the candidate shall be required to show that, for each of the testing methods for which he seeks certification, he has at least half of the time required.

5) The maximum possible reduction in duration of experience shall be limited to 50 percent.

6) Minimum educational qualification is X standard (with Science and Maths).

5.3.5 In leak testing there can be reduction in training hours, if candidate is taking limited leak testing methods.

5.3.6 All candidates for level III certification in any NDT method shall have successfully completed (with a grade ≥ 70 percent) the practical examination for level II in that method.

5.4 Vision Requirements

The candidate shall provide documented evidence of satisfactory vision as determined by a medically person or the employer, in accordance with the following requirements:

a) Near vision acuity shall permit reading a minimum of Jaeger Number 2 or equivalent type and size letters at a distance of not less than 30 cm on a standard Jaeger test chart with one or both eyes, either corrected or uncorrected;

b) Colour vision shall be sufficient that the candidate can distinguish and differentiate between the colours used in the NDT method concerned. Colour vision to be tested as per ISHIHARAS charts; and

c) Subsequent to certification, the tests of visual acuity shall be carried out annually and be verified by the employer or the responsible agency.

Table 2 Minimum Experience Requirements, Level III

(*Clause* 5.2)

Method of Access (1)	Education (2)	Experience Month [1] [2] (3)
Access to level III by a certified level II operator	Degree in engineering, post-graduate in science from an accredited science or engineering college or university programme	12
	Diploma in engineering, degree in science from an accredited college or university	24
	X standard with Science and Maths	48
Direct access to level III NOTE — The candidate shall have successfully completed the practical examination for level II in that NDT method.	Degree in engineering, post-graduate in science from an accredited science or engineering college or university programme	24
	Diploma in engineering, degree in science from an accredited college or university	48
	X standard with Science and Maths	72

[1] If the college or university degree is issued in non-destructive testing, the experience required for access to level III may be reduced by 50 percent.

[2] Credit for work experience may be gained simultaneously in two or more of the NDT methods covered by this standard, with the reduction of total required experience as follows:

a) two testing methods — reduction of total required time by 25 percent;

b) three testing methods — reduction of total required time by 33 percent; and

c) four or more testing methods — reduction of total required time by 50 percent.

6 QUALIFICATION EXAMINATIONS — CONTENT AND GRADING

6.1 Qualification Examinations for Level I and Level II

This qualification examination administered under this standard shall include a general examination. Examination shall consist of written part and a practical part. The practical part shall be of sufficient duration, complexity and scope to adequately verify the candidate's ability to apply the NDT method to real test situations.

6.1.1 *General Examination*

In general examination, the candidate shall demonstrate proficiency in performing the relevant NDT method.

The written test of the general examination shall include questions selected from the National Certifying Body's collection of basic knowledge questions valid at the date of examination. The candidate shall be required, as a minimum, to give answers to a number of multiple choice questions as given in Table 4. The examination would be of closed book type and the time allowed to the candidates for completion of each examination shall be based upon the number and difficulty of the questions.

The practical test of the general examination is to verify the candidate's ability to make the required settings and operate the test equipment properly in order to obtain satisfactory results and correctly interpret these results. The candidate, therefore, shall be required to demonstrate this ability, with comments, using the means of verification available for each test method, such as, calibration blocks, image quality indicators, magnetic field indicators, etc (whichever is relevant).

For level II examination, there will be questions on interpretation of code, and interpretation of discontinuity indications to test candidates knowledge in that field. These questions may be from any product sector (that is, welds, castings, forgings, etc) or combination of sectors.

Table 3 Minimum Training Requirements

(*Clauses* 5.3.1, 5.3.2 *and* 5.3.3)

NDT Method		Level I hours 1)4)5)	Level II hours 1)2)4)5)	Level III hours 1)4)5)	
				Basic	Method
(1)		(2)	(3)	(4)	(5)
AT		40 3)	64	40	40
ET		40 3)	40	40	40
IRT		40	40	40	24
LT	a) Basic knowledge	40	46	40	40
	b) Bubble test (BT)	2	4		
	c) Pressure change test (PCT)	24	24		
	d) Halogen diode leak test (HDLT)	12	12		
	e) Mass spectrometer leak test (MSLT)	40	24		
MT		16	24	40	24
NRT		28	40	40	40
PT		16	24	40	16
RT		40	40	40	40
UT		40	40	40	40
VAT		24	80	40	40
VT		16	24	40	24

1) Training hours include both practical and theory courses.

2) Direct access to level II examination requires the total hours shown for level I and level II.

3) 40 hours are equivalent to the duration of a week of work.

4) Training duration may be reduced by up to 50 percent when the certification sought is limited in application or technique.

5) A reduction of up to 50 percent in the total required number of training hours may be accepted by the certification body for candidates who have graduated from technical college or university, or have completed at least two years of engineering or science study at college or university.

Table 4 Required Minimum Number of Questions — General Examination Level I and II

(*Clauses* 2.14 *and* 6.1.1)

Sl No.	NDT Methods	Number of Questions	
		Level I	Level II
(1)	(2)	(3)	(4)
i)	Acoustic emission testing	40	40
ii)	Eddy current testing	40	40
iii)	Leak testing	30	30
iv)	Liquid penetrant testing	30	30
v)	Magnetic particle testing	30	30
vi)	Neutron radiography	40	40
vii)	Radiographic testing	40	40
viii)	Thermal imaging	40	40
ix)	Ultrasonic testing	40	40
x)	Vibration analysis testing	40	40
xi)	Visual testing	30	30

6.1.2 *Specific Examination*

This examination will normally be conducted by the employer for the specific technique/industrial sector. However, at the request of the employer this may also be conducted by the National Certifying Body or the authorised qualifying bodies. In the specific examination, the candidate shall demonstrate his ability to use the relevant test method in the industrial sector concerned. The written test of specific examination shall include questions based on codes/specifications used in concerned sector/employer.

During the specific written examination, the candidate shall be required as a minimum, to give answers to number of questions as a defined in Table 5. These will be multiple choice questions. For level I these will be based on written procedure/technique sheet and for level II these will be based on codes/standard/specification discontinuities, their causes, interpretation of indications etc. for the components related to that sector.

The practical test of the specific examination is to verify the candidate's ability to perform testing of prescribed components relating to the industrial sector concerned, to record and to analyze the resultant information to the degree required to specific testing instructions or specifications, and to the NDT level being sought.

Table 5 Required Number of Questions — Specific Examination

(*Clause* 6.1.2)

Sl No.	NDT Methods	Number of Questions	
		Level I	Level II
(1)	(2)	(3)	(4)
i)	Acoustic emission testing	20	20
ii)	Eddy current testing	20	20
iii)	Liquid penetrant testing	20	20
iv)	Leak testing	20	30
v)	Magnetic particle testing	20	20
vi)	Neutron radiography testing	20	20
vii)	Radiographic testing	20	20
viii)	Infrared testing	20	20
ix)	Ultrasonic testing	20	20
x)	Vibration analysis testing	20	20
xi)	Visual testing	20	60

6.1.3 *Practical Examination Content*

a) The practical examination shall involve applying the test to prescribed specimens, recording (and for level II candidates, interpreting) the resulting information to the degree required and reporting the results in the required format;

b) Each specimen shall be uniquely identified and have a master report which includes all of the equipment settings used to detect specified discontinuities contained within the specimen;

c) The master report shall be complied based upon at least two independent tests, and shall be validated by an authorised level III certificate holder for use in grading examinations;

d) Specimens shall contain discontinuities characteristic of those which occur during manufacturing or in service. Discontinuities may be natural, artificial or implanted;

e) The number of areas or volumes to be tested shall be adequate to the level and NDT method, and to the sector concerned, and shall contain reportable discontinuities. The requirements for the number of areas or volumes to be tested in the levels I and II practical examination is given in Tables 6 and 7);

f) The level I candidate shall follow the NDT instruction(s) provided by the examiner;

g) The level II candidate shall select the applicable NDT technique and determine the operating conditions related to a given code, standard, or specification;

h) The time allowed for examination depends on the number of specimens and their complexity. The recommended maximum time is:
   1) For level I, three hours.
   2) For level II, four hours.

j) Level II candidates shall draft at least one NDT Instruction suitable for level I personnel. The recommended maximum time allowed for this part of the examination is two hours; and

k) The grading of the practical examination, with the

Table 6 Minimum Number and Type of Test Specimens for the Levels I and II Practical Examination — Techniques AT, ET, IRT, LT, MT and NRT

(*Clause* 6.1.3)

Method/ Level Product Sectors	AT1	AT2	ET1	ET2	IRT1	IRT2	LT1	LT2	MT1	MT2	NRT1	NRT2
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Castings	1	1+2 datasets	2	2	1	1+2 datasets	2	2	2	2	2	2+6 radiographs
Forgings	1	1+2 datasets	2	2	1	1+2 datasets	2	2	2	2	2	2+6 radiographs
Welds	1	1+2 datasets	2	2	1	1+2 datasets	2	2	2	2	2	2+6 radiographs
Tubes and Pipes	1	1+2 datasets	2	2	1	1+2 datasets	2	2	2	2	2	2+6 radiographs
Wrought Products	1	1+2 datasets	2	2	1	1+2 datasets	2	2	2	2	2	2+6 radiographs

Table 7 Minimum Number and Type of Test Specimens for the Levels I and II Practical Examination — Techniques PT, RT, UT, VAT and VT

(*Clause* 6.1.3)

Method/ Level Product Sectors (1)	**PT1** (2)	**PT2** (3)	**RT1** (4)	**RT2** (5)	**UT1** (6)	**UT2** (7)	**VAT1** (8)	**VAT2** (9)	**VT1** (10)	**VT2** (11)
Castings	2	2	2	2+12 radiographs	2	2	1	1+2 datasets	2	2
Forgings	2	2	2	2+12 radiographs	2	2	1	1+2 datasets	2	2
Welds	2	2	2	2+12 radiographs	2	2	1	1+2 datasets	2	2
Tubes and Pipes	2	2	2	2+12 radiographs	2	2	1	1+2 datasets	2	2
Wrought Products	2	2	2	2+12 radiographs	2	2	1	1+2 datasets	2	2
Industrial Sectors (which include two or more products)	i) The specimens tested shall be representative of all products, or shall be selected at random by the examiner from the product range which makes up the sector. ii) For radiographic film interpretation, the number of radiographs interpreted shall be not less than eight for each relevant product sector encompassed by an industrial sector.									

weighting in relation to the level, shall be as detailed in Table 8.

6.1.4 *Conduct of Examination*

General examinations shall be conducted in examination centres approved and monitored by the National Certifying Body either directly or through an authorised qualifying body.

At the examination, the candidate shall have in his possession a valid proof of identification and an official notification of the examination, which must be shown to the examiner or invigilator on request.

Any candidate who does not abide by the examination rules during the course of the examination or who perpetrates or is an accessory to fraudulent conduct will be excluded from further participation.

The written and practical tests should be conducted and supervised by an examiner chosen among NDT level III personnel and designated by the national certifying body. The examiner may be assisted by one or more invigilators placed under his responsibility.

The examiner shall mark the written tests completed by the candidate. He shall judge and mark the results of the practical tests according to a procedure which includes at least ten check points. This procedure shall be developed by the National Certifying Body or an authorized qualifying body.

A candidate for a practical examination may use his own apparatus. The examiner should investigate the reliability of the test apparatus made available to the candidate, and unreliable apparatus should be replaced as well as any apparatus that may be rendered unserviceable during the course of the examination. Any item of apparatus brought by a candidate that is unreliable or rendered unserviceable during the examination should be replaced by the candidate/course organizer.

6.1.5 *Grading*

To be certified, the candidate shall obtained a grade of at least 70 percent each in written and practical tests and a composite grade of at least 80 percent.

The composite grade of the respective level shall be determined by adding the weighted marks obtained from multiplying each of the test marks by a weighing factor Table 9.

Table 8 Percentile Weighting for Level I and II Practical Examination

(*Clause* 6.1.3)

Subject (1)	**Level I** (2)	**Level III** (3)
Part 1: Knowledge of the NDT apparatus		
a) System control and functional checks	10	5
b) Verification of settings	10	5
Total	20	10
Part 2: Application of the NDT method		
a) Preparation of the test piece (for example, surface condition), including visual examination	5	2
b) For level II, the selection of the NDT technique and determination of operating conditions	—	7
c) Setting up of the NDT apparatus	15	5
d) Performance of the test	10	5
e) Post test procedures (for example, demagnetisation, cleaning, preservation)	5	1
Total	35	20
Part 3: Detection of discontinuities and reporting (*see* Note 1)		
a) Detection of mandatory reportable discontinuities	20	15
b) Characterisation (type, position, orientation, apparent dimensions, etc)	15	15
c) Level II evaluation against code, standard, specification or procedure criteria	—	15
d) Redaction of the test report	10	10
Total	45	55
Part 4: NDT instruction writing (level II candidates) (*see* Note 2)		
a) Foreword (scope, reference documents), status and authorisation		1
b) Personnel		1
c) Apparatus to be used, including settings		3
d) Product (description or drawing, including area of interest and purpose of the test)		2
e) Test conditions, including preparation for testing		2
f) Detailed instructions for application of the test		3
g) Recording and classifying the results of test		2
h) Reporting the results		1
Total		15
Overall grade for practical specimen	100%	100%

NOTES

1 The candidate failing to report a discontinuity specified on the specimen master report as 'mandatory for candidates to report' when performing the test in the conditions specified in the master report will be awarded zero marks for Part 3 of the practical examination related to the specimen tested.

2 The level II candidate is required to produce an NDT instruction, suitable for level I personnel, for a specimen selected by the examiner. When the level II candidate is testing a specimen for which no NDT instruction is required, the grade is calculated as a percentage of the 85 remaining marks.

Table 9 Weightage Factors for Grading
(*Clause* 6.1.5)

Level	Weighting Factor	
	Written	Practical
(1)	(2)	(3)
I	0.4	0.6
II	0.6	0.4

Same grading criteria may be used by the employer for grading specific examination.

6.1.6 *Re-examination*

A candidate who failed to obtain the passing grade may reappear in the examination after a period of 3 months but within 12 months without taking fresh training. If he fails again, he has to undergo full training course before appearing for the examination.

A candidate failing for reason of unethical behaviour must wait at least 12 months before re-applying. A candidate for re-examination shall apply for and take the examination according to the procedure established for new candidates.

6.1.7 *Examination for Level III*

6.1.7.1 *Examination content*

The qualification examination for level III candidates shall consist of written examination on basic, method and specific examination on method. Basic examination is required only once. When more than one method examination is taken or when the candidate appears in other methods later on after passing level III in one method, he need not appear for basic examination when he adds his qualification in any other method. The specific test method applies to one or more industrial sectors.

6.1.7.2 *Basic examination*

The basic examination shall include only multiple choice questions, selected from the National Certifying Body's collection of basic knowledge questions valid at the date of the examination. The number of questions shall be as follows:

a) 45 questions on material, processes, discontinuities, metallurgy, material testing, metrology, QA, etc;
b) 50 questions based on knowledge of all NDT methods; and
c) 5 questions on knowledge of certification body's qualification and certification system based on the National and International Standards.

The basic examination should be passed first and remains valid, provided that the first main method examination is passed within five years after passing the basic examination.

6.1.7.3 *Method examination*

Each method examination shall be in two parts. The first part is designated as general and the second as specific.

The general examination shall include 80 questions on principles, equipments, techniques, applications and advances of particular NDT method. The necessary questions shall be chosen from a list maintained by the National Certifying Body.

There will be separate specific paper for each industrial sector.

Each specific examination shall consist of two parts. Part 1 shall have 20 multiple choice questions on application of NDT method in that sector, interpretation of indications and interpretation of code/specification. Part 2 shall consist of drafting one or more satisfactory NDT procedures in industrial sector concerned.

If candidate is appearing for more than one specific examination in a particular NDT method, he shall appear separately for each specific examination. However general paper will be common.

6.1.8 *Conduct of Examinations*

All examinations shall be conducted in examination centres established or approved by the National Certifying Body, and shall be monitored by the National Certifying Body, directly or through an authorised qualifying body.

For the examination, the candidate shall have in his possession valid proof of identification and an official notification of the examination. These must be shown to the examiners on request. Any candidate who during the course of the examination does not abide by examination rules, or who pertrates or is an accessory to fraudulent conduct, shall be excluded from further participation.

Examination should be conducted and supervised by at least two monitors designated by the National Certifying Body, directly or through an authorized qualifying body.

Each examiner shall correct and grade separately the different parts of the examination according to procedures established by the National Certifying Body. During a meeting each one of the assigned examiners shall present and explain his grades and an average grade shall be calculated for each part of the examination.

6.1.9 *Grading*

Written basic examination shall be graded separately so that the candidate may be examined later for certification in another method without having to repeat the basic examination. The candidate shall obtain a grade of at least 80 percent in the basic examination.

In the method examination, a candidate shall obtain a grade of at least 70 percent in each part of the examination and a composite grade of at least 80 percent.

The composite grade for method examination shall be determined by adding the marks after taking into account weightage factor obtained from multiplying the test marks in each part of the examination by a weighting factor to be selected from Table 10.

To be certified, the candidate must pass in Basic as well as in Method examination. To qualify in any other NDT method, candidate can appear in 'Method' examination only. To qualify for additional specific sector in a particular method, candidate has to appear in 'General' as well as 'specific' papers

Table 10 Weightage Factor for Specific Examination — Level III

(*Clause* 6.1.9)

General (1)	Specific (2)
0.5	0.5

6.1.10 *Re-examination*

A candidate failing for reason of unethical behaviour must wait at least 12 months before re-applying.

A candidate who failed to obtain the passing grades may take one and only one, retest within 12 months without undergoing the course. In the case of second failure in obtaining the passing grade, the candidate shall take examination according to the procedure applicable to new candidates.

7 SUGGESTED SECTORS

The following are the suggested product, industrial and specific sectors. The employer may choose any specific sector or a combination of sectors. For purposes of certifications, while the general guidelines regarding examination and its conduct would be as recommended by this standard, however, the scope and syllabus shall be as prescribed by the employer in his written documents. Certification may be available at all three levels of competence in all NDT methods or may be limited to particular methods or levels given below. The scope of certification should be clearly defined based on the Levels given in this standard.

7.1 Product Sectors

a) Castings (ferrous and non-ferrous materials) [c];
b) Forgings (all types of forgings; ferrous and non-ferrous materials) [f];
c) Welds (all types, including brazing soldering for ferrous and non-ferrous materials) [w];
d) Tube and pipe (seamless, welded, ferrous and non-ferrous materials including flat products for the manufacture of welded pipes) [t]; and
e) Wrought products except forgings (plates, bars, rods) [wp]

7.2 Industrial Sectors

Sectors combining a number of product sectors including all or some products or defined material (for example, ferrous and non-ferrous material, or non-metals, such as, ceramics, plastics and composites).

a) General engineering (combining c/f/t/w and wp);
b) Pre and in-service testing of equipment, plant and structure (combining c/f/w/t and wp);
c) Railway maintenance (combining f, wp and other product sectors); and
d) Aerospace (combining c/f/w/t/wp and other product sectors)

An individual holding certification in a particular industrial sector may be regarded also has holding certification in the individual sectors from which the multi-sector is composed.

7.3 Job Specific Sectors (Annex B Syllabus)

a) Eddy current and electromagnetic sorting of materials,
b) Eddy current and electromagnetic testing of tubular products during manufacture,
c) Radiographic film interpretation,
d) Normal beam ultrasonic testing of plate materials during manufacture, and
e) Ultrasonic thickness testing.

8 CERTIFICATION

8.1 Administration

Based on the results of the qualification examination, the National Certifying Body, directly or through its authorized qualifying bodies, shall announce the certification and issue certificates and corresponding wallet cards to the successful candidates. To procure and handle the radiography source, the permission of the competent authority (Atomic Energy Regulatory Board) will be necessary.

8.2 Certificates and Wallet Cards (Only for Level III)

Certificates and corresponding wallet cards shall bear:

a) Full name of the certified individual;
b) Date of certification;
c) Date upon which certification expires;

d) Level of certification;
e) NDT method;
f) Industrial sector(s) concerned (for level III only);
g) A unique identification number;
h) Signature of the certified individual;
j) A photograph of the certified individual;
k) Seal of the National Certifying Body or the approved qualifying body cancelling the photograph to avoid falsification; and
m) Signature, on the certificate, of a designated representative of the certification body.

NOTE — By issuing the certificate and/or the corresponding wallet card, the National Certifying Body or the qualifying body attests to the qualification of the individual but does not give any authority to operate. There may be a special space on both the certificate and the wallet card for the signature of the employer or responsible agency authorizing the holder of the certificate to operate and taking responsibility for test results. This authorization also serves as testimony of activity of the certified individual.

8.3 Validity

The period of validity of the certificate shall be five years from the date of certification indicated on the certificate and/or wallet card:

Certification shall be invalid:

a) if the individual changes from one industrial sector to another, in which case, he must successfully complete supplementary examinations, for the new industrial sector;
b) if the individual becomes physically incapable of performing his duties or a significant interruption takes place in the individual's work within the scope of the certificate;
c) if the individual fails to meet the vision acuity requirements mentioned in **5.4**; and
d) At the option of the National Certifying Body after reviewing evidence of unethical behaviour.

NOTE — A significant interruption means an absence or a change of activity which prevents the certified individual from practicing the duties corresponding to his level in the method for which he is certified, for a continuous period exceeding one year. If the criteria for renewal are not met, the individual shall apply for re-certification.

8.4 Renewal

8.4.1 *Level I and II*

After the period of validity, certification may be renewed by the National Certifying Body, directly or through an authorized qualifying body, for an additional period of five years from the date of expiry provided the individual meets the following criteria:

a) Provides evidence of satisfactory visual examination; and
b) Provides evidence of continued satisfactory work activity without significant interruption.

Applications for renewal can be made up to 6 months before the date of expiry.

8.4.2 *Level III*

In the case of level III personnel re-certification by ISNT is intended to apply only to individuals who maintain continued active employment in NDT level III functions and demonstrate efforts to keep abreast of the technology in the method(s) for which re-certification is sought.

Recertification can be obtained by application subject to the following conditions:

a) Reaffirmation of the 'Code of Ethics' for level III Non-destructive Testing Personnel Certified by ISNT and as prescribed in the NCB Quality Manual;
b) Continued active employment in level III functions as related to the NDT Method(s) for which recertification is sought;
c) Such employment must have covered at least 36 months during the valid certification period, but not necessarily 36 consecutive months;
d) At least 12 of the 24 months immediately preceding the expiration of the certification must have been spent in level III functions; and
e) If work experience during the certification period did not include all methods for which re-certification is sought, at least two additional points shall be obtained in each method for which there was not work experience.

The demonstration of an effort to keep up-to-date, contribute to knowledge or maintain continued growth in the method(s) for which the individual is certified or to expand knowledge in related technologies by obtaining a minimum number of points during each 5 year period of certification as given in Table 11.

To be re-certified, it is necessary to gain a minimum of 30 points in a 5 year period. A maximum of 10 points per year will be allowed.

8.5 Annulment of Qualification

a) Effective period expired with no application made for qualification continuation;
b) Certificate holder is seized with a serious disorder either mental or physical;
c) A serious fault was committed by the certificate holder in his qualification related work; and
d) Certificate holder has injured the certification board's reputation or conducted against the purpose of the certification board.

8.6 Re-certification

In case the candidates fails to renew his existing certificates, to regain certification for that method (and sector), the candidate shall be required to apply for fresh certification and has to undergo the appropriate method examination (general and specific) including practicals in the case of level I and II.

9 FILES

The National Certifying Body or its authorized qualifying bodies shall maintain either in hard copy form or read only digitised (electronic) form :

a) An updated list of all certified individuals classified according to level, test method and industrial sector; and

b) Files containing following papers for each individual who have appeared in the certifying examination :

   1) Application forms;
   2) Examination documents, including questionnaires, answers, description of specimens, records, results of test, written procedures and/or techniques, and grade sheets;
   3) Renewal documents, including evidence of physical condition and continuous activity; and
   4) Reasons and penalty for any withdrawal of certification.

NOTE — Files shall be kept under suitable conditions of safety and confidentiality as long as the certificate remains valid and for at least 2 years after certification has lapsed.

Table 11 Credit System for Level III Re-certification

(*Clause* 8.4.2)

Item	Activity	Points Accorded for Each Item (or Function)	Maximum Points per Year per Item
(1)	(2)	(3)	(4)
1	Attendance at national (NDE) and international seminars, workshops, symposia, conferences and/or courses covering NDT and related sciences and technologies	3	6
2.1	Attendance at International and National Standards committees	1	1
2.2	Convenership of standards committees	2	2
2.3	Contributions to formulation/revision of standards	2	2
3.1	Attendance at sessions of other NDT committees and working groups	1	1
3.2	Convenership of sessions of other NDT committees and working groups	1	1
4.1	NDT related technical/scientific contributions or publications including presentations in national/international conferences, seminars or workshops	3	6
4.2	NDT related research work published	3	6
4.3	NDT research activity	3	6
5	Faculty for NDT training/refresher courses per method or NDT examiner (per examination) Industrial activity	1	2
6.1	Responsibility for a test facility or NDT method in an examination center (for each full year)	5	10
6.2	Development of NDT applications, procedure development	1	3

NOTE — To be re-certified, it is necessary to gain a minimum of 30 points in a 5 year period. A maximum of 10 points per year will be allowed.

ANNEX A

(Foreword)

SYLLABUS AND TRAINING HOURS OF DIFFERENT METHODS

Inspection Method: Eddy Current Testing
Summary

Sl No.	Subject	Hours of Training		
		Level I	Level II	Level III
(1)	(2)	(3)	(4)	(5)
i)	General knowledge	4	4	—
ii)	Physical principles	8	6	7
iii)	Instrumentation	8	12	10
iv)	Testing procedure	14	12	10
v)	Applications	4	4	4
vi)	Presentation of results	2	2	4
vii)	Quality assurance and standardization	—	—	2
viii)	Organization and administration of NDT	—	—	2
ix)	Qualification and certification of NDT personnel	—	—	1
	Total	**40**	**40**	**40**

Inspection Method : Eddy Current Testing
Level I

Subject 1 **General Knowledge** **4 h**

1.1 Non-destructive testing of materials, Definitions, Reasons for using NDT, Description and field of application of the most common methods, Comparison between methods.

1.2 Materials, Discontinuities, Defects, Properties of materials, Properties of metals.

1.3 Defects originating from melting, pouring, cooling. Processing defects from welding, forging, rolling, heat treatment, machining, plating, etc, service defects due to overload, fatigue, corrosion, brittle fracture and others.

Subject 2 **Physical Principles** **8 h**

2.1 **Electricity**

Direct current : (a) Amperage and voltage, (b) Ohm's law and resistance, (c) Conductivity and resistivity Alternating current, (a) Amplitude and phase, (b) Impedance

2.2 **Magnetism**

Magnetic data : (a) Induction and magnetic fields, (b) Magnetic permeability, (c) Iron magnetization Induced magnetic flux, (a) Definition, (b) Lines of force and force fields, (c) Flux conservation, residual magnetism

2.3 **Electromagnetism**

Magnetic field produced by a current, Current induced by a magnetic field eddy current inductance, Field created by eddy current — Resistance, Lenz's Law

2.4 **Eddy Current Distribution**

Plane conductors : (a) Variation of amplitude and phase of current, (b) Standard depth of penetration, (c) Defect reaction according to position

Cylindrical bars : (a) Characteristic frequencies, (b) Variation of amplitude and phase of currents, (c) Standard depth of penetration, (d) Defect reaction according to position

Tubes : (a) Characteristic frequencies, (b) Variation of amplitude and phase of currents, (c) Standard depth of penetration, (d) Defect reaction according to position

Subject 3	**Instrumentation**	**8 h**

3.1 Principles and basic characteristics of eddy current probes, Induction and reception functions, Absolute and differential measure, Types of probes

3.2 Reaction of different types of probes according to coil layout, Reaction to small defects, Reaction to long defects, Reaction to continuous defects

3.3 Technology and practical characteristic of probes, Design technology, Electrical parameters, maintenance

3.4 Working principle of eddy current equipment: Transmission, Reception, Data presentation

3.5 Adjustment of eddy current equipment: Frequency, Energizing device, Balancing, phase rotation, Output filter, Gain

3.6 Different types of eddy current equipment: Monoparameter, monochannel and specialized equipment, Output devices

3.7 Auxiliary devices: Auxiliary devices for signal acquisition, driving mechanism — Saturating unit — Demagnetiser, Equipment for signal storage : Stripchart recorders, magnetic tape recorders, digital memories, System for automatic processing of signals

Subject 4	**Testing Procedures**	**14 h**

4.1 Influence of defect position and orientation eddy current path, Penetration depth, Zone of probe action, Influence of material temperature, Heating, Deviations and Compensation

4.2 Influence of structure and geometry of tested parts (noise): Choice of test frequency, Phase discrimination, Filtering, Magnetic saturation, Coupling influence, Vibrations, Centring — Fill Factory, Sensitivity, Compensation, Influence of relative part/probe speed, Testing frequencies according to speed, Bandwidths of apparatus according to testing speed, Reference standards used in eddy current testing, Function of reference standards, Choice of reference standards, Fabrication and reproducibility of various types of reference standards, Inspection, Method, Range of inspection, Recording of indications.

Subject 5	**Applications**	**4 h**

5.1 Geometric defect characterization: Hypothesis of interrupted currents, Case of point defects, Case of large defects, Case of multiple defects.

5.2 Main types of discontinuities detected by eddy current testing, Discontinuities arising from production, Discontinuities arising during hot or cold processing, Discontinuities arising during service, Defect detection, Absolute measurement, Differential measurement, Thickness measurement, Thickness of a product, Thickness of coating, Measurement of product composition, measuring by electrical conductivity.

Subject 6	**Presentation of Results**	**2 h**

6.1 Written procedures, Report preparation

Eddy Current Testing, Level I — Practicals

a) Equipment familiarization: (1) Impedance plane type, (2) Meter type
b) Testing of specimen with different geometry and structure
c) Influence of coupling, probe speed and material temperature, etc, on testing of specimen

Demonstrations: a) Absolute and differential probe responses
b) Conductivity measurements
c) Choice of frequencies

Inspection Method: Eddy Current Testing
Level II

Subject 1	General Knowledge	4 h

1.1 Basic principles of NDT, Definitions and methodology of applications, Areas of application of common methods, Range and limitations of common methods

1.2 Materials and defects, Structure of metals and alloys, Physical and mechanical properties of metallic materials, Discontinuities and defects in metallic materials

1.3 Processing defects, primary processes and related defects, Manufacturing processes and related defects

1.4 Materials in service: Behaviour of materials in service, Service conditions leading to defects and failures: (a) Corrosion, (b) Fatigue, (c) Wear, (d) Overload, (e) Brittle fracture, Concept of rupture in development in metals

1.4 Quality and standardization: Definition of quality, Quality control and standardization, Development of a quality system, Examination, Testing and inspection, Standards, Codes, Specifications and procedures, Reports, Records and Protocols

Subject 2	Physical Principles	6 h

2.1 **Electricity**

Direct current: (a) Amperage and voltage, (b) Ohm's law and resistance, (c) Conductivity and resistivity
Alternating current: (a) Amplitude and phase, (b) Impedance

2.2 **Magnetism**

Magnetic data : (a) Induction and magnetic fields, (b) Magnetic permeability, (c) Iron magnetization

Induced Magnetic flux: (a) Definition, (b) Lines of force and force fields, (c) Flux conservation, residual magnetism

Magnetic Ohm's law: (a) Magnetomotive force, (b) Reluctance, (c) Magnetic circuit

Magnetic Field produced by a current Biot and Savart law: (a) Definition, (b) Practical rules, (c) Right hand rule

Ampere's law: (a) Definition, (b) Applications (toroid, infinite coil, flat coil)

2.3 **Electromagnetic Induction Law**

Lenz's law: (a) Definition, (b) Auto-induction factor, (c) Mutual induction factor, (d) Coupling factor

Induced currents: (a) In a short-circuit coil, (b) In a metallic mass, (c) Skin effect, (d) Field created by eddy current, (e) Field resistance

2.4 **Eddy Current Distribution**

Plane conductors: (a) Variation of amplitude and phase of current, (b) Depth of standard penetration, (c) Defect reaction according to position

Cylindrical bars: (a) Characteristic frequencies, (b) Variation of amplitude and phase of currents, (c) Depth of standard penetration, (d) Defect reaction according to position

Tubes: (a) Characteristic frequencies, (b) Variations of amplitude and phase, (c) Defects reaction according to position

Subject 3 **Instrumentation** **12 h**

3.1 Principles and basic characteristic of eddy current probes, Induction and reception functions, Absolute and differential measures, Types of probes

3.2 Eddy current distribution relative to coil position, Field generated by non-load inductor coil, Eddy current path in a part according to its position relative to inductor coil, Distance influence on coupling in various shapes, Focusing methods

3.3 Reaction of different types of probes according to coil layout, Reaction to small defects, Reaction to long defects, Reaction to continuous defects

3.4 Technology and practical characteristics of probes, Design technology, Manufacturing technology, Electrical parameters, maintenance use of ferrite cores, Shielding of probes, rotating probes.

3.5 Working principles of eddy current equipment, Transmission, Reception, Data presentation

3.6 Main functions and adjustments of the equipment, Oscillator, Energizing device, Measuring system, Balance, Amplifier and filter, Demodulator, Display (eclipse, timebase, impedance plane, vector point), Phase rotation, Output filter

3.7 Different types of eddy current equipment, Monoparameter, Monochannel and specialized equipment, Multiparameter and multichannel equipment

3.8 Auxiliary devices for signal acquisition, driving mechanism — Saturating unit — Demagnetizer, Equipment for signal storage: Recorders, magnetic tape recorders, digital memories system for automatic processing of signals

Subject 4 **Testing Procedures** **12 h**

4.1 Influence of defect position and orientation Eddy current path, Penetrationdepth, Zone of probe action, Influence of material temperature, Heating, Deviations and Compensation

4.2 Influence of structure and geometry of tested parts (noise), Choice of frequency, Phase discrimination, Filtering, Magnetic saturation

4.3 Coupling influence, Vibrations, Centering-fill factor, Sensitivity, Compensation

4.4 Influence of relative part/probe speed, testing frequencies according to speed, Bandwidths of apparatus according to testing speed

4.5 Reference standards used in eddy current testing, Function of reference standards, Choice of reference standards, Fabrication and reproducibility of various types of reference standards, Inspection method, Range of inspection, Recording of indication, Analysis and interpretation of results

Subject 5 **Applications** **4 h**

5.1 Geometric defect characterization: Hypothesis of interrupted currents, Case of point defects, Case of large defects, Case of multiple defects, Coil with a long conductive product (bar or tube), Impedance diagram, Influence of various parameters, Ferromagnetic products

5.2 Use of impedance diagrams: Definition of operating point, Choice of operating point according to sensitivity of parameter splitting

5.3 Electromagnetic properties of materials, Electrical conductivity, Chemical analysis, Temperature, Grain size texture influence, Structure, Magnetic permeability: Chemical analysis, Structure, Grain size and Texture influence

5.4 Main type of discontinuities detected by eddy current testing: Discontinuities arising from production, Discontinuities arising during hot or cold processing, Discontinuities arising during service

5.5 Defect detection, Absolute measurement, Differential measurement

5.6 Thickness measurement, Thickness of a product, Thickness of coating

5.7 Measurement of product composition, Measuring by electrical conductivity

5.8 Multi-frequency eddy current testing, Principles, Equipment, Applications

Subject 6	Presentation of Results	2 h

6.1 Codes and standards which apply to eddy current testing

6.2 Specifications and procedures which apply to the method

6.3 Inspection techniques and their use

6.4 Inspection reports

Eddy Current Testing, Level II — Practicals

a) Equipment familiarization
b) Influence of defect position and orientation on specimen testing
c) Influence of material temperature on specimen testing
d) Influence of structure and geometry of tested part
e) Influence of coupling on specimen testing
f) Influence of relative speed between test part and probe
g) Defect detection by absolute and differential methods
h) Thickness measurements of products and coatings
j) Determination of product composition by electrical conductivity methods
k) Use of multiple frequency probe eddy current testing method for product testing — support plate simulation, ferromagnetic deposit simulation
m) Crack detection by impedance plane instrument and meter type instrument — differences
n) Inspection problems with ferromagnetic materials

Inspection Method: Eddy Current Testing
Level III

Subject 1	General Knowledge (covered in Basic)	

Subject 2	Physical Principles	7 h

2.1 Phenomena of electromagnetic induction, Field generated by a current, Field/induction relationship, Flux of induction vector, Electromotive force of induction, Self-inductance — Coefficient of self-inductance, Mutual inductance — Coefficient of mutual, inductance — Coupling coefficient

2.2 Impedance of a circuit in the presence of another circuit, Representation of impedance plane, Effect of variation in fill factor, Normalized impedance plane, Effect of variation in frequency, Influence of a magnetic field

2.3 Electromagnetic wave propagation, Basic laws: Application to a plane wave incident at a plane conductor — decreasing delay of fields and currents and phase, Definition of the standard penetration depth (*d*), Expression of (*d*) in the specific case of plane, Definition of the similarity law

2.4 Eddy current distribution in test pieces, bars: Simplifying hypothesis, similarity law, limit frequency, eddy current distribution (amplitude, phase), standard penetration depth tubes : Simplifying hypothesis, similarity law, Different expressions of limit frequency, eddy current distribution (amplitude, phase), Standard penetration depth, Field applied to short test pieces, Similarity law, Simplifying hypothesis, Limit frequency in simple cases of magnetic materials, Field applied to surfaces, Complexity due to different parameters, Characterization of geometrical discontinuities, Hypothesis of interrupted currents, Point defects, Extensive defects, Multiple defects, Impedance diagrams for specific cases: Feed through coils, bars, tubes, short test pieces in feed through, operating points, sensitivity

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Subject 3	**Instrumentation**	**10 h**

3.1 Principles and basic characteristic of eddy current probe, Induction and reception functions, Absolute and differential measurement, Test coil arrangements: Encircling coil, Internal coil, Surface coil, Hybrid coil, Focusing means: Magnetic circuits, Coil arrangements

3.2 Use of probes: Field from empty short coil, Divergence between practice and theory, Difference in coupling and current distribution resulting from different coil arrangements

3.3 Working principle of eddy current equipment, Transmission, Reception, Data presentation

3.4 Main functions and adjustments of the equipment oscillator, Energizing device, Measuring system, Balance, Amplifier and filter, Demodulator, Display (Eclipse, time-base, impedance plane, vector point), Phase rotation, Output filter

3.5 Classification of eddy current equipment, one parameter equipment: specialized equipment, one way equipment, Multiparameter equipment: Two way equipment, multi-frequency equipment

3.6 Auxiliary devices — Auxiliary devices for signal acquisition. Driving mechanism — saturating unit — demagnetizer, Equipment for signal storage: Strip chart recorders, magnetic tape recorders, digital memories, System for automatic processing of signals, Computer Interfaces — Advantages

Subject 4	**Testing Procedures**	**10 h**

4.1 Influence of defect position and orientation eddy current path, penetration depth, zone of probe action

4.2 Influence of materials temperature, Heating, Deviation and Compensation

4.3 Influence of structure and geometry of tested parts (noise), Choice of test frequency, phase discrimination, Filtering, Magnetic saturation

4.4 Coupling influence, Vibrations, Centring — Fill factor, Sensitivity, Compensation, Influence of relative part/probe speed. Testing frequencies according to speed, Bandwidths of apparatus according to testing speed

4.5 Reference standards used in eddy current testing, Function of reference standards, Choice of reference standard, Fabrication and reproducibility of various types of reference standards

4.6 Inspection method, Range of inspection, Recording of indications, Analysis and interpretation of results

Subject 5	**Applications**	**4 h**

5.1 Electromagnetic properties of materials, Electrical conductivity, Effects of chemical composition, Temperature, grain size and structure. Magnetic-permeability, dia, para and ferromagnetic materials. Hystresis loop, Raleigh area, saturation, Weiss area, Curie point, Effect of chemical composition, grain size and structure

5.2 Anomalies related to manufacture and use of products: Related to the manufacture of cost, extruded or rolled products, Related to service: Creep, fatigue, corrosion

5.3 Defect detection, Absolute measurement, Differential measurement

5.4 Thickness measurement, Thickness of a product, Thickness of coating, Measurement of product composition, Measuring by electrical conductivity

5.5 Recent developments in eddy current testing, Multifrequency eddy current testing — Principles, Applications, Pulsed eddy current testing — Principles — Applications, Electromagnetic transducers — Principles of conversion

— advantages, Theoretical Modelling — advantages, Remote Field eddy current testing — principles, applications, Magnetic flux leakage methods

5.6 Problems encountered in eddy current inspection position and orientation of defects — eddy current paths — penetration depth, Structure and geometry of the test pieces-noise — frequency — phase discrimination, Lift-off — vibrations — centring — sensitivity, Coil specimen relative speed-test frequency as a function of speed, Temperature — overheating — drift — compensation, Equipment — reproducibility of measurement — deviation of equipment characteristics — calibration.

Subject 6 Presentation of Results 4 h

6.1 Codes and standards which apply to eddy current testing, Specifications and procedures which apply to the method, techniques and their use, Inspection reports

6.2 Report writing

Subject 7 Quality Assurance and Standardization 2 h

7.1 Quality assurance, Basic principles for the application of quality assurance, Organization of quality assurance, Quality manual, Quality control, Auditing of quality

7.2 Management and control of quality assurance documentation, Quality testing, Documentation systems

7.3 Standardization, Definition of standardization, Principles of standards writing, Standards, Codes, Specifications and procedures, their uses, Reports and protocols

Subject 8 Organization and Administration of NDT 2 h

8.1 **Organization and administration of NDT**

Safety: (a) Implementation of industrial safety standards in facilities and equipment and in their operation, (b) Hazards of using toxic and inflammable materials, (c) Materials, accessories and equipment for the protection of persons and facilities

Organization: (a) Equipment for work under way, logistic problems; (b) Testing on production lines, Flow of materials, work shifts; (c) Maintenance of equipment and facilities

Costs: (a) Investment in equipment, (b) Direct and indirect staff costs, (c) Calculation and analysis of costs and profitability

8.2 Equipment selection and facility design, Operating procedures, Record keeping

Subject 9 Qualifying and Certification of NDT Personnel 1 h

9.1 Qualification and certification of personnel for NDT, National standards for the qualification and certification of personnel. Regional and international recommendations, training of personnel for NDT. Organization of courses and training in NDT methods, Code of ethics

Inspection Method : Liquid Penetrant Testing
Summary

Sl No.	Subject	Hours of Training		
		Level I	Level II	Level III
(1)	(2)	(3)	(4)	(5)
i)	General knowledge	4	4	—
ii)	Physical principles of the tests	3	4	3
iii)	Processing	5	6	4
iv)	Test equipment and materials	2	7	2
v)	Codes, standards, procedures and safety	2	3	2
vi)	Quality assurance and standardization	—	—	2
vii)	Organization and administration of NDT	—	—	2
viii)	Qualification and certification of NDT personnel	—	—	1
	Total	**16**	**24**	**16**

Inspection Method : Liquid Penetrant Testing
Level I

Subject 1 **General Knowledge** **4 h**

1.1 Non-destructive testing of materials, Definitions, Reasons for using NDT, Description and field of application of the most common methods, Comparison between methods

1.2 Materials, Discontinuities, Defects, Properties of materials, Properties of metals

1.3 Defects originating from melting, pouring, cooling, Processing defects from welding, forging, rolling, hear treatment, machining, plating, etc, Service defects due to overload, fatigue, corrosion, brittle, fracture and others.

Subject 2 **Physical Principles of the Test** **3 h**

2.1 Definitions of basic terms as viscosity, surface tension etc, Description of the method. Properties of penetrating liquids: Wetability (expansion of the drop), Penetration, Bleeding and influence of the surface state, the contamination and the temperature. Concepts of solutions and comparisons: Solvents, dispersive agents and emulsifiers, Concepts relating to the mechanism of development: Powder granulometry, and suspension. Basic concepts relating to colour and fluorescence, Dyes, Fluorescent pigments and UV and light radiation (black light). Composition of oily and non-oily penetrating liquids: Composition and/or properties of removers: Organic solvents and emulsifiers. Composition and state of developers: Dry developers and wet developers

Subject 3 **Processing** **5 h**

3.1 Preparation of the specimen: Treatment, Identification, and Temperature. Cleaning prior to inspection: Solvents, Types and techniques of use, Detergent solutions, Chemical action solutions (acids, alkalis, removers), Inhibition and rinsing, Use of ultrasonic agitation, Mechanical media, brushing, grinding, sanding, etc, and Conditions and limitations on their use. Drying — Drying requirements, Cold and hot air, and temperature and time. Application of the penetrant: Various modes of application, penetrant on time and temperature, removal of excess penetrant: Various methods of removal depending on type of penetrant: (a) Water dispersible, (b) Water-soluble, (c) Solvent-soluble, (d) Post-emulsifiable, and (e) Drying. Application of the developer: Various techniques for application of the developer and previous treatment of the developer. Observation of indication of coloured and fluorescent penetrating liquids, lighting requirements, observation sequence and time, and False or irrelevant indications. Final cleaning. Recording of the finding: Test Forms, Transfer of findings, Diagrams, and Photography

Subject 4	Test Equipment and Materials	2 h

4.1 Evaluation of the materials for testing: Characteristic properties, Behaviour properties and Content of halogen, sulphur and other specific contaminants. Cleaning equipment: Ultrasonic and degreasing steam. Pulverizers and aerosols. Installations for processing by immersion: Lighting, and Measuring equipment and units, Lighting: Measuring equipment and units. Ultra-violet, radiation lamps (black light). Efficiency types and characteristics, Measurements of ultraviolet radiation intensity, and units (micron X/cm^2)

Subject 5	Codes, Standards, Procedures and Safety	2 h

5.1 General knowledge: National, regional and international codes and standards, General knowledge of specifications. Industrial safety standards: Instructions for the test — Interpretation

Liquid Penetrant Testing, Level I — Practicals

a) Equipment familiarization, and
b) Specimen testing.

Inspection Method : Liquid Penetrant Testing, Level II

Subject 1	General Knowledge	4 h

1.1 Basic principles of NDT, Definitions and methodology of applications, Areas of application of common methods, Range and limitations of common methods

1.2 Materials and defects, Structure of metals and alloys, Physical and mechanical properties of metallic materials, Discontinuities and defects in metallic materials

1.3 Processing defects, primary processes and related defects, Manufacturing processes and related defects

1.4 Materials in service: Behaviour of materials in service, Service conditions leading to defects and failures: (a) Corrosion, (b) Fatigue, (c) Wear, (d) Overload, (e) Brittle fracture, Concept of rupture in development in metals

1.5 Quality and standardization: Definition of quality, Quality control and standardization, Development of a quality system, Examination, testing and inspection, Standards, Codes, Specifications and Procedures, Reports, records and protocols

Subject 2	Physical Principles of the Test	4 h

2.1 General description of the method. Properties of liquid penetrants: Viscosity, surface tension, angle of contact between liquid and solid, capillarity, Behaviour of liquid penetrants twistability, penetrability, washability, retention and bleeding, and Influence if the surface state of the sample, contamination and temperature. Solutions and dispersions: Solvents and dispersive agents, lipophilic and hydrophilic emulsifiers. Mechanism of development: Granulometry of powders, types and phenomena of fine powder aggregation, and suspension of powders in liquids.

Luminous and ultraviolet spectrum, resolving power: Colour and fluorescence, colours, absorption of light, Beer's law, and fluorescent pigments. Basic formulation of penetrating liquids with oily and non-oily base — additives and conditioners. Removers used in the process — Basic formulation and properties, emulsifiers, lipophilic and hydrophilic agents. Composition and state of developers — Granulometry and developers in the dry state and in liquid suspensions.

Subject 3	Processing	6 h

3.1 Preparation of the work piece, treatment, identification and protection of the areas not to be examined. Cleaning prior to inspection — Various techniques applicable: (a) Solvents vapour degreasing, (b) Detergent solutions,

(c) Solutions having a chemical action (acid and alkali removers, etc), ultrasonic cleaning, and (d) Mechanical means (grinding, sanding, brushing, etc). Conditions and limitations of the different cleaning techniques. Comparison of the effectiveness of the different techniques in relation to the surface state of the specimen

3.2 Conditions and requirements for the different drying stages — use of cold and hot air, temperature and time. Inspection process — Application of the penetrating agent : (a) Application techniques, (b) Temperature, and (c) Penetration time

3.3 Removal of excess penetrating agent : (a) Various methods of removal depending on type of penetrant: dispersible, water soluble, solvent soluble, post-emulsifiable, (b) Conditions for the application lipophilic and hydrophilic emulsifiers, (c) Drying, and (d) Requirements and precautions in the removal stage. Application of the developer: (a) Various techniques and (b) Previous treatment of the developer.

3.4 Observation of the findings: Lighting conditions for coloured liquids and UV radiation for fluorescent liquids. Sequence and time of observation, interpretation of the findings and identification of the type of defects, and spurious or non-relevant findings.

3.5 Recording of findings: Test forms, Localization schemes, Transfer of findings, photographic techniques and writing reports

3.6 Testing techniques for detection of leaks by means of liquid penetrants.

Subject 4 **Test Equipment and Materials** **7 h**

4.1 Evaluation of the materials used in the test: (a) Characteristic properties: viscosity, density, surface tension, ignition point, halogen and sulphur content, colour, fluorescence, and (b) Behaviour: drop expansion, washability, corrosion, preservation, stability under light and UV radiation.

4.2 Removers: Characteristics properties and behaviour, Granulometry and apparent volume, Sedimentation and compaction. Emulsifiers — Characteristic properties and behaviours

Developers : (a) Characteristic properties and behaviour, (b) Granulometry and apparent volume, (c) Sedimentation, (d) Evaluation of process, and (e) Use of standardized work pieces.

4.3 Cleaning equipment: Degreasing vapour and Ultrasonic — Compressed air equipment — Air filters, supply of cold and hot air, Compressed air pistals, Electrostatic pulverizers and aerosols. Stationary installations for processing by immersion — automatic installations. Light sources and lightmeters, Ultra-violet radiation sources (black light and meters for measuring ultra-violet radiation intensity, checking the efficiency of ultraviolet lamps and Cabinets for observation of fluorescent penetrating liquids. Standardized work pieces for evaluating processes and qualifying procedures, test pieces, Non-standardized test pieces for checking penetrability, Equipment for checking fluorescence and efficiency of ultra-violet lamps.

4.4 Penetrant system evaluation through Ni-Cr panels, comparator blocks, etc.

Subject 5 **Codes, Standards, Procedures and Safety** **3 h**

5.1 Standards applicable to liquid penetrant test — Test methods, Materials for the test and. Test specifications and procedures — interpretation and formulation of instructions for the test. National standards for liquid penetrant test and testing personnel : (a) Quality control of the test and procedure for its administration, and (b) Quality assurance requirements. Problems of industrial safety in the use of chemical and inflammable products — Applicable safety standards, Safety conditions required for the use of ultra-violet light, Drafting of safety instructions for the personnel involved, and Safety factors applicable to the test

Liquid Penetrant Testing, Level II — Practicals

a) Equipment familiarization,
b) Specimen testing, and
c) Interpretation of test results.

Inspection Method — Liquid Penetrant Testing
Level III

Subject 1	General Knowledge (covered in Basic)	

Subject 2	Physical Principles of the Test	3 h

2.1 Review of physical, chemical and physico-chemical principles for applying the method. Liquid-solid interface phenomena solutions and dispersions. Solvents and dispersing agents lipophilic and hydrophilic emulsifiers. Physico-chemical mechanisms determining penetration, emulsification and developing. General spectrum of electromagnetic radiation. Luminairs spectrum, ultra-violet and infrared radiation. Wood radiation (black light). Measurement and units. Colour and fluorescence. Light absorption phenomena. Beer's law. Absorption spectrometry. Fluorescent emission spectra. Mechanism of vision. Conditions for visual observations. Perception of light, colour and contrast. Systems of weighting units and thresholds.

Subject 3	Processing	4 h

3.1 Selection of the test techniques in relation to the type of specimen and design specifications. Treatment and preparation of the specimens: Protection of areas not being examined, selection of techniques for preparation and preliminary cleaning, systems of cleaning, design and monitoring and intermediate drying, conditions and requirements for the various techniques. Application of the penetrating agent — comparison of the various techniques, Determination of special conditions depending on the examination requirements, acceptable temperature intervals, special cases of high and low temperature and penetration time. Removal of the excess penetrating agent: Removal techniques for the various systems, design and monitoring of the removal stage, Post-emulsification, and Lipophilic and hydrophilic emulsifiers. Techniques of development: Treatment of the specimens prior to development, various types of developers, and Treatment, selection and control. Observation of the indications: Lighting conditions and wood radiation requirements, depending on the application techniques and characteristics of the specimen, Method, time and sequence of the observations, and methods and media for recording indications. Evaluation of test sensitivity: Test pieces for comparison, defection thresholds, and interpretation of indications depending on fabrication process, false, spurious or irrelevant indications, and Evaluation of indications according to specifications, codes or tolerance criteria. Classification of the application techniques: Criteria for classification and selection and operational conditions. Test techniques for detecting leaks by means of penetrating liquids and evaluation of areas of applications and sensitivity.

Subject 4	Test Equipment and Materials	2 h

4.1 Formulation of the penetrating liquids in various techniques: Types of dyes pigments. Penetrants for prior cleaning and for removal, Solvents, Lipophilicand hydrophilic emulsifiers, characteristics and properties, Developers, Physico-chemical properties and characteristics and form of presentation and use. Evaluation of materials: Characteristic properties and behaviour, Test methods for the evaluation, standardized test pieces for evaluation of process: rating of procedures. Equipment and accessories applicable to the test under way: Pulverization systems and equipment for liquids, Isothermic and adiabatic compressors. Lectrostatic pulverizers, stationary installations for manual and automatic processing, Lighting for direct observations and ultra-violet radiation sources: Measuring instruments and devices for evaluating pigment fluorescence and efficiency of ultra-violet lamps.

Subject 5	Codes, Standards, Procedures and Safety	2 h

5.1 Examination specifications: Function of design engineering, Design and building codes. Standards specific to liquid penetrant testing: National and International Standards and Interpretation of specifications, codes and standards, testing procedures: Formulation of test procedures and general and specific procedures. Safety in penetrant testing

Subject 6	Quality Assurance and Standardization	2 h

6.1 Quality assurance: Basic principles for the application of quality assurance, organization of quality assurance, quality manual. Quality control, auditing of quality. Management and control of quality assurance documentation, Quality control of testing. Reports on testing, documentation systems. Standardization: 3 Ls + definition of standardization, report principles of standards writing, writing standard, codes, specifications and procedures, their uses, and reports and protocols.

Subject 7 **Organisation and Administration of NDT** **2 h**

7.1 Safety: Implementation of industrial safety standards in facilities and equipment and in their operation, hazards of using toxic and inflammable materials, and materials, accessories and equipment for the protection of persons and facilities.

Organization: Equipment for work under way, logistic provisions, testing on production lines, flow of materials, work shifts, maintenance of equipment and facilities.

Costs: Investments in equipment, direct and indirect staff costs, calculation and analysis of costs profitability.

7.2 Equipment selection and facility design. Operating procedures and record keeping.

Subject 8 **Qualification and Certification of NDT Personnel** **1 h**

8.1 Qualification and Certification of personnel for NDT: National standards for the specification and certification of personnel, regional and international recommendations, training of personnel for NDT. Organization of courses and training in NDT methods and code of ethics.

Inspection Method : Magnetic Practicle Testing
Summary

Sl No.	Subject	Hours of Training		
		Level I	Level II	Level III
(1)	(2)	(3)	(4)	(5)
i)	General knowledge	4	4	—
ii)	Physical principles and fundamentals of magnetic particles	3	4	5
iii)	Methods and techniques	4	6	5
iv)	Equipment and accessories	2	4	4
v)	Codes, standards, specifications and procedures	2	2	3
vi)	Presentation and recording of results	1	2	1
vii)	Interpretation of results, limitations	—	2	1
viii)	Quality assurance and standardization	—	—	2
ix)	Organization and administration of NDT	—	—	1
x)	Qualification and certification of NDT personnel	—	—	1
	Total	**16**	**24**	**24**

Inspection Method : Magnetic Particle Testing
Level I

Subject 1 **General Knowledge** **4 h**

1.1 Non-destructive testing of materials, Definitions, Reasons for using NDT, Description and field of application of the most common methods, Comparison between methods.

1.2 Materials, Discontinuities, Defects, Properties of materials, Properties of metals.

1.3 Defects originating from melting, pouring, cooling. Processing defects from welding, forging, rolling, hear treatment, machining, plating, etc, service defects due to overload, fatigue, corrosion, brittle, fracture and others. Particle test method, General principles of electricity and magnetism

Subject 2 — Physical Principles and Fundamentals of Magnetic Particles — 3 h

2.1 Electricity: Current, voltage, resistance, alternating current and direct current measurement and devices

2.2 Magnetism: Magnetic poles, permanent magnets, temporary magnets, permeability, ferromagnetic, paramagnetic and diamagnetic materials, magnetic fields, lines of force, magnetic fields around the conductor solenoid, electromagnet, magnetic flux, magnetization force, reluctance and hystersis, units in magnetism.

2.2 Visible and ultra-violet light, method of testing by magnetic particles.

Subject 3 — Methods and Techniques — 4 h

3.1 Methods of magnetization: Longitudinal, circular and vertical. Magnetization techniques: Permanent magnets, electromagnets, coils, passage of current and central conductor. Inspection techniques: Remnant fields, continuous field, wet method, dry method, and verification of magnetic fields. Demagnetization techniques and verification of remnant fields.

Subject 4 — Equipment and Accessories — 2 h

4.1 Knowledge of equipment: permanent magnets, magnetic yokes, portable and stationary equipment, types of current, test current capacity, and demagnetization equipment. Conditions of use: Equipment operation, equipment maintenance and safety. Accessories: Contact points, vessels for checking inspection baths, field indicator (Berthold test piece), Calibration test pieces, Magnetic field measurement equipment, ultraviolet lamps, coloured and fluorescent powders, and colour for increasing contrast.

Subject 5 — Codes, Standards, Specifications and Procedures — 2 h

5.1 Interpretation of written instructions for application of tests by different techniques. Wet suspension of coloured and fluorescent particles preparation and standards

5.2 Working with magnetic field: Magnetic field test, Measurement of magnetic filed and demagnetization of work pieces

5.3 Codes, Standards and Specifications – General knowledge of codes and standards, and general knowledge of specifications and procedures

Subject 6 — Presentations and Recording of Results — 1 h

6.1 Presentation of results on test forms, Recording of indications — To locate and identify them with reference to the test piece, by photography, and by using transfer methods, Recognition of findings: Indications of defects and spurious (false indications).

Magnetic Particle Testing, Level I — Practicals

a) Equipment familiarization, and
b) Specimen testing

Magnetic Particle Testing
Level II

Subject 1 — General Knowledge — 4 h

1.1 Basic principles of NDT, Definitions and methodology of applications, Areas of application of common methods, Range and limitations of common methods.

1.2 Materials and defects, Structure of metals and alloys, Physical and mechanical properties of metallic materials, Discontinuities and defects in metallic materials.

1.3 Processing defects, primary processes and related defects, Manufacturing processes and related defects.

1.4 Materials in service: Behaviour of materials in service, Service conditions leading to defects and failures: (a) Corrosion, (b) Fatigue, (c) Wear, (d) Overload, (e) Brittle fracture, Concept of rupture in development in metals.

1.5 Quality and standardization: Definition of quality, Quality control and standardization, Development of a quality system, Examination, testing and inspection, Standards, Codes, Specifications and procedures, Reports, records and protocols.

Subject 2 — Physical Principles and Fundamentals of Magnetic Particles — 4 h

2.1 Electricity — current, voltage, resistance, alternating current, and direct current, Measurement techniques, Amperes law, Faraday rule.

2.2 Magnetism — magnetic poles, permanent magnets, temporary magnets, Ferro, Para, and diamagnetic materials, magnetic fields, lines of force, magnetic field around a conductor, solenoid, electromagnet magnetic flux magnetization force reluctance, hystersis. B-H curve.

2.3 Magnetic field characteristics — Resonance, Permeability, Saturation, and Normal and tangential compounds of the magnetic field, Terminology and abbreviations, Electromagnetic wave visible and ultra-violet light.

Subject 3 — Methods and Techniques — 6 h

3.1 Methods of magnetization — longitudinal and circular magnetization techniques — Permanent aspects, electromagnets, cells, by passage of current and by induction.

3.2 Work methods — remnant field, continuous field dry method and wet method.

3.3 Testing techniques — for work pieces of differing alloys, shape and conditions, with various types of current, field direction for some specific cases, appropriate field intensity, and test sequences.

3.4 Miscellaneous field practices — preparation of the wet and dry suspension for coloured and fluorescent particles, techniques for checking field sensitivity: (a) field indicators for calibration test pieces, (b) work pieces for evaluating magnetic particles, and reasons for demagnetization: (a) operating conditions, and (b) testing the effectiveness of demagnetization.

Subject 4 — Equipment and Accessories — 4 h

4.1 Knowledge of equipment — permanent aspects, magnetic yoke, portable and stationary equipment, types of current and concepts of testing capacity, demagnetization equipment and maintenance and use of equipment Accessories — contact points, vessels for checking both concentration, field indicators (Berth old test pieces), calibration pieces, magnetic field measurement equipment (Gauss meter), ultra-violet lamps, coloured and fluorescent powders, colour for increasing contrast, and morphology of the particles. Selection of equipment appropriate to the nature of the test-special equipment — portable equipment, stationary installations and automated equipment.

Subject 5 — Codes, Standards, Specifications and Procedures — 2 h

5.1 Interpretation of procedures for the application of test using various techniques, composition of test procedures including instructions for various methods and techniques for use with work pieces of various materials and shapes, with selection of equipment, field detection, intensity, types of current, selection of inspection medium, type of particle, sequence of testing, demagnetization.

5.2 Standards — qualification and certification of personnel, internal specification and corresponding standards, and codes and standards.

Subject 6	Presentation and Recording of Results	2 h

6.1 Preparation of reports on the testing, preparation and compilation of the report form. Documentation of the findings: (a) to locate the indication within the component, (b) by the use of sketching and photography, (c) transfer method using adhesive tape, (d) knowledge of documentation systems, and (e) management and control of complete documentation.

Subject 7	Interpretation of Results, Limitations	2 h

7.1 Presentation of results, Thresholds of detection : (a) evaluation of results, according to the criteria of the procedure and specification, and (b) additional possibilities for making the results more conclusive. Interpretation of findings with reference to the manufacturing processes. Applications of magnetic particle testing and other methods of testing for surface and subsurface flaws.

Magnetic Particle Testing, Level II — Practicals

a) Equipment familiarization,
b) Specimen testing, and
c) Interpretation of results.

Inspection Method : Magnetic Particle Testing
Level III

Subject 1	General Knowledge (covered in Basics)	

Subject 2	Physical Principles and Fundamentals of Magnetic Particles	1 h

2.1 Magnetism: Theory and characteristics of the magnetic fields, Demagnetizing effect and Separation of the magnetic field. Magnetic inductions in materials: Permeability in ferromagnetic and non-ferromagnetic materials and film effect. Magnetic fields: Generation of magnetic fields and Basis for the calculation of magnetization systems. Use of Hysterisis loop, Measurement of magnetic fields and electromagnetic fields. Electromagnetic radiations: Visible light, wood radiation, physical concepts, measurement and equipment, Conditions for visual observation, Luminance thresholds and Visual acuity.

Subject 3	Methods and Techniques	2 h

3.1 Magnetization: Magnetization methods, Magnetization techniques: (a) Types of magnetic field application, (b) Intensity and type of current, (c) Combined magnetization, (d) Incremental permeability. Modes of operation: Continuous field, Conditions for application of the inspection medium, and Remanant field. Indicating medium: physical chemical conditions necessary for the particles and suspension vehicles. Wet and dry methods. Fluorescent particles. Conditions for applying the indicating medium. Evaluation: Verification of the sensitivity of the test. Determination of the applicability of the various field indicators. Verification of visibility conditions and requirements for existing fluorescence. Correlation between defectology, the test findings and the technique applied. Demagnetization: Reasons for demagnetizing. Evaluation of remanent magnetic fields. Requirements and conditions for demagnetization in accordance with the technique of the test use and the material examined.

Subject 4	Equipment and Accessories	2 h

4.1 Equipment: Selection for purchase, conditions of use and maintenance of equipment for magnetization and demagnetization, portable, permanently installed or automated. Design basis of systems for testing accessories: Design, selection and use of accessories for various testing techniques. Field indicators: (a) Analysis and comparison of the various field indicators, and (b) Method of application and evaluation of application. Instruments for magnetic field measurement, use of Gauss meter. Various types of wood radiation lamps and UV meters Methods of indication: Magnetizable particles: (a) Chemical and physical characteristics, Morphology and dimensions, and (b) Various types coloured and fluorescent, Suspension vehicles for test by wet methods preparation and evaluation of indication media for test by wet and dry methods, ac and dc demagnetization equipment. Demagnetization equipment basic on the oscillatory discharge of condenser.

Subject 5 Codes, Standards, Specifications and Procedures 2 h

5.1 Specifications of the examination. Function of design engineering. Design and building codes, Standard: Specific standards for tests with magnetic particles, Interpretation of specifications, codes and standards. Procedures: Formulation of test procedures. General and specific procedures.

Subject 6 Presentations and Recording of Results 1 h

6.1 Preparation of reports on the testing. Preparation and completion of the report form. Documentation of the findings: (a) to locate the indication within the component, (b) knowledge of documentation systems, (c) management and control of complete documentation.

Subject 7 Interpretation Results, Limitations 1 h

7.1 Presentation of results. Thresholds of detection: (a) Evaluation of results according to the criteria of the procedure and specifications, and (b) Additional possibilities for making the results more conclusive. Interpretation of the findings with reference to the manufacturing process. Applications of magnetic particle testing and other methods of testing for surface and sub-surface flaws.

Subject 8 Quality Assurance and Standardization 5 h

8.1 Quality assurance: Basic principles for the application of quality assurance. Organization of quality assurance. Quality manual. Auditing of quality, management and control of quality assurance documentation, quality control of testing. Reports on testing, documentation system.

8.2 Standardization: Definition of standardization, principles of standards writing. Standards, Codes, Specifications and procedures, their uses. Reports and protocols. Report writing.

Subject 9 Organizations and Administration of NDT 7 h

9.1 Organization and Administration of NDT — Safety: (a) Implementation of industrial safety in facilities and equipment and in their operation, (b) Hazards of using toxic and inflammable materials, (c) Materials, accessories and equipment for the protection of persons and facilities.

Organization: (a) Equipment for work under way; Logistic provisions; (b) Testing on production lines, Flow of materials, Work shifts, Maintenance of equipment and facilities.

Costs: (a) Investment in equipment, (b) Direct and indirect staff costs, (c) Calculation and analysis of costs and profitability.

9.2 Equipment selection and facility design. Operating procedures and record keeping.

Subject 10 Qualifications and Certification of NDT Personnel 2 h

10.1 Qualification and certification of personnel for NDT, National standards for the qualification and certification of personnel, Training of personnel for NDT Organization of courses and training in NDT methods, Code of ethics

Inspection Method : Radiographic Testing (Summary)

Sl No.	Subject	Hours of Training		
		Level I	Level II	Level III
(1)	(2)	(3)	(4)	(5)
i)	General knowledge	4	4	—
ii)	Physical principles of the test	3	6	2
iii)	Equipment — Radiation sources	3	3	3
iv)	Photographic and non-photographic recording	3	4	3
v)	Work parameters and conditions	7	5	5
vi)	Defectology	3	2	4
vii)	Selection of techniques	4	3	3
viii)	Selection of test methods according to standards, etc	3	3	3
ix)	Personal safety and radiation protection	6	4	3
x)	Special applications	—	2	2
xi)	Recording and interpretation	2	2	2
xii)	Other radiography techniques	—	1	1
xiii)	Advances in radiography	2	1	3
xiv)	Quality assurance and standardization	—	—	2
xv)	Organization and administration of NDT	—	—	2
xvi)	Qualification and certification of NDT personnel	—	—	2
	Total	**40**	**40**	**40**

Inspection Method : Radiographic Testing
Level I

Subject 1	**General Knowledge**	**4 h**

1.1 Non-destructive testing of materials, Definitions reasons for using NDT, description and field of application of the most common methods, Comparison between methods.

1.2 Materials, discontinuities, defects, properties of material, properties of metal.

1.3 Defects originating from melting, pouring, cooling. Processing defects from welding, forging, rolling, hear treatment, machining, plating, etc, service defects due to overload, fatigue, corrosion, brittle, fracture, and others.

Subject 2	**Physical Principles of the Test**	**3 h**

2.1 Elements of Atomic and Nuclear Physics, Principles of radioactive decay and radioactivity, Half life, Artificial and natural sources, etc, Penetrating radiation, X-rays and gamma-ray spectra, KVp - KeV, inverse square law for distance/intensity.

2.2 Interaction of radiation with matter, absorption/dispersion/photoelectric effect/Compton effect/pair production, Absorption coefficient/Half thickness and tenths value layer, etc.

2.3 Detection of ionizing radiation.

Subject 3 Equipment — Radiation Sources 3 h

3.1 X-ray equipment, Generators and tubes/head, control cabinet, power source and accessories.

3.2 Gamma ray sources – types, spectrum, activity, shielding and handling.

Subject 4 Photographic and Non-photographic Recording 3 h

4.1 Photographic recording (X-ray and gamma-ray), Film / Principles/ properties, Emulsions/classes/ characteristic curves. Lead and fluorescent screens, Types of film for industrial radiography, Basics of image intensifier and fluoroscopy systems.

Subject 5 Work Parameters and Conditions 7 h

5.1 Parameters and work conditions, Image density/factors affecting it, Geometric principles/penumbra, Image quality, contrast and definition, Disperse radiation/causes/control uses of screens/masks/filters, Exposure curves/ X-rays/gamma-rays/exposure calculations, Image quality indicators/procedure for selection and placement.

5.2 Care in handling and conservation of film. Darkroom equipment, chemicals, processing of the film.

5.3 Viewing of radiographs, General background/lighting/viewers.

5.4 Evaluation of radiograph quality, Causes and corrections of defective radiographs, Film artefacts processing defects/high density/low density/contrast/definition/fog. Image quality indicators, Identification, Density measurements.

Subject 6 Defectology 3 h

6.1 Basic relationship between image and object.

6.2 Radiographic indication of defects.

Subject 7 Selection of Techniques 4 h

7.1 Influence of the properties of the material, Exposure techniques according to the geometry of the object. Single wall/single image, Double wall/single image, Double wall/double image. Panoramic exposure. Thickness compensation masks, Latitude techniques.

Subject 8 Selection of Test Methods According to Standards, etc 3 h

8.1 Influence of properties of the material, General knowledge of codes and standards, General knowledge of specifications and procedures, Performance of tests in accordance with written instructions, recording of tests.

Subject 9 Personal Safety and Radiation Protection 6 h

9.1 Biological effects, Somatic and genetic effects.

9.2 Radiation units and maximum permissible doses.

9.3 Method of controlling exposure: Time/Distance/Shielding specific requirements of safety for operation of X-ray and gamma-ray equipment, Monitoring /recording, shielding for exposure/ bunkers, Operation/warning systems, Operational and emergency procedure.

9.4 Legislation packaging and transport.

Subject 10	Advances in Radiography	2 h

10.1 Brief over-view of advantages and applications of microfocal radiography, high energy radiography and real time radiography, neutron radiography.

Radiographic Testing, Level I — Practicals and Demonstrations

a) Demonstration of operation of X-ray machine and gamma-ray camera,
b) Demonstration of use of lead screens, fluorescent screens and fluoroscopic, systems-manual on various brands of films,
c) Viewing of Radiographs — Demonstration,
d) Practical — Taking radiograph of a given sample,
e) Demonstration — Relating defects and its image on radiograph,
f) Demonstration — Selection of test method according to standards, and
g) Radiation Monitoring Instruments.

Inspection Method : Radiography Testing
Level II

Subject 1	General Knowledge	4 h

1.1 Basic principles of NDT, Definitions, Methodology of applications, Areas of application of common methods, Range and limitations of common methods.

1.2 Materials and defects, Structure of metals and alloys, Physical and mechanical properties of metallic materials, Discontinuities and defects in metallic materials.

1.3 Processing defects, primary processes and related defects, Manufacturing processes and related defects.

1.4 Materials in service, Behaviour of materials in service, Service Conditions leading to defects and failures : (a) corrosion, (b) Fatigue, (c) Wear, (d) Overload, (e) Brittle fracture, Concepts of rupture development in metals.

1.5 Quality and standardization, Definition of quality, quality, control, standardization. Development of a quality system, Examination, testing and inspection, Standards, Codes, Specifications and procedures, Reports, records and protocols.

Subject 2	Physical Principles of the Test	6 h

2.1 Elements of atomic and nuclear physics, Elements of radioactive decay, Alpha, beta, gamma and neutron radiations. The nature of penetration radiations, Corpuscular and Electromagnetic radiation, X-rays and gamma-rays, Wave length and energy, X-ray and gamma-ray spectra, KVp- KeV, Inverse square law for distance/ intensity, General properties of the propagation of penetrating radiation, production of isotopes.

2.2 Interaction of radiation with matter, Absorption dispersion/photoelectric effect/ Compton effects/pair production, Absorption coefficient. Half value and tenth value thickness, use of tables, for calculating attenuation coefficient.

2.3 Radiation units, Exposure, Absorbed dose, Dose equivalent, Radioactivity etc, Dose equivalent, Radioactivity etc, Dose intensity and concept of specific emission.

2.4 Principles of X-ray and gamma-ray detection, Method of ionization/electronics, Film/Fluorescent material. Accuracy of measurements, Limits of application.

Subject 3	Equipment — Radiation Sources	3 h

3.1 X-ray equipment, Generators and X-ray tubes/materials and target characteristics/configurations/focus/heat dissipation, Head/control cabin/power source, auxiliaries, equipment design, emission, work cycle, Determination of focus.

3.2 Gamma-ray sources, Type of spectrum/activity/shielding, Handling, Exposure techniques, Decay schemes, Energy spectrum, Emission factor, Use of Collimation.

3.3 High energy Radiography Sources — Linac.

Subject 4	**Photographic Recording**	**4 h**

4.1 Photographic recording (Gamma-ray, X-ray), Film/Principles/ Properties, Emulsions, types characteristic curves/ radiographic quality, Lead and fluorescent screens, Types of films for industrial radiography, Use of sensitometeric curves, Exposure curves, Brightness and penumbra responses of fluorescent screens.

Subject 5	**Parameters and Work Conditions**	**5 h**

5.1 Parameters and working conditions. Image density/factors which affect it. Geometrical principles/penumbra, Image quality/contrast and definition, Disperse radiation cause control, Use of screens/masks/filters, Exposure calculations, Image quality indicators/positioning, Interpretation of test instructions, Choice of films, Preparation of exposure curves, Choice of screens. Magnification and distortion of the projection image, Fluoroscopy: evaluation of sensitivity/ selection of KVp.

5.2 Film processing, Principle of image formation, Processing in darkroom, Equipment reagents, care to be taken in handling and conserving the film, Checking on the use of reagents/temperatures/processing time. Special situations, Safety lamps.

5.3 Viewing of the radiographs, General information/lighting/viewer, Influence of the observation conditions on the detection of defects checking the lighting in viewer, Brightness requirements.

5.4 Evaluation of radiographic quality, Causes and correction of defective radiographs, processing defects/high density/contrast/definition fog, Image quality indicators, Identification, Density measurement, Systematic control of radiographic quality.

Subject 6	**Defectology**	**2 h**

6.1 Basic factors, Relation between image and object, General information on the nature of discontinuities in radiography, interpretation of radiographic images. Use of radiographs welding, casting, corrosion, etc.

Subject 7	**Selection of Techniques**	**3 h**

7.1 Influence of the properties of the material, compound materials, Exposure technique depending on the geometry and accessibility of the object. Single wall/single image, Double wall/single image. Double wall/ double image, panoramic exposure. Thickness compensation, Masks, Filters, Detection probability depending on type, size, position and orientation of the defect/high and low sensitivity techniques.

Subject 8	**Selection of Test Methods Depending on Codes, Standards, etc**	**3 h**

8.1 General knowledge of codes and standards, General knowledge of specification and procedures interpretation of procedures and compilation of test instruments. Performance test in accordance with written instructions, Records of operating conditions on test forms, Evaluation of tasks carried out by level I operators, Instructions for testing in special situations, Range of application of the test, equipment and technique.

Subject 9	**Personal Safety and Radiation Protection**	**4 h**

9.1 Dangers of excessive exposure to X-rays and gamma-rays (biological effects), Somatic and genetic effects.

9.2 Maximum permissible doses.

9.3 Methods of reducing exposure time/distance/shielding, Specific safety requirements for the operation of X- and gamma-ray equipment, Monitoring/recording devices — Principles, applications and range of detection. Shielding of exposure/bunkers, Calculation of shielding and distances.

9.4 Legislation.

9.5 Procurement, packaging and transport.

9.6 Operational and emergency procedures, accident report + 3 Safety experiments.

Subject 10	Special Applications	2 h

10.1 Multiple film techniques, Projection and magnification techniques, panoramic exposure, determination of depth of defects. Radiography of radioactive objects.

Subject 11	Recording of Test and Interpretation Results	2 h

11.1 The recording of test, Test documentation, Evaluation of results and according to standards and application of codes.

Subject 12	Other Radiography Techniques	1 h

12.1 Neutron Radiography, Electron Radiography, Xeroradiography — Principles and applications.

Subject 13	Advances in Radiography	1 h

13.1 Micro focal radiography, real time and digital X-radiography, Tomography and Image Processing — Brief outline of Principles and Applications.

A Radiography Testing, Level II — Practicals

a) Familiarization with radiography equipment (X-ray and gamma-ray) and their operation.
b) Dark room practices and preparation of sensitometric curves.
c) Evaluation of reference radiographs.
d) Relating discontinuities with the radiographic images of standard defects in castings, welds and materials having corrosion.
e) Selection of radiography technique for various samples of different material and geometries,
f) Preparation of test procedures as per different codes,
g) Determination of depth of flaw, and
h) Preparation of model reports, acceptance, repair or rejection of materials based on given radiographs.

B Radiation Safety

a) Familiarization with radiation safety equipment, monitors, dosimeters, warning symbols, etc;
b) Procurement, transport and packaging of radioisotopes (Demonstration);
c) Area monitoring; and
d) Radiation accidents.

Radiography Testing Syllabus
Level III

Subject 1	General Knowledge (covered in Basic)	

Subject 2	Physical Principles of the Test	2 h

2.1 Nature of ionizing radiation, Corpuscular and electromagnetic radiation, X-rays and gamma-rays.

2.2 Radioactive decay, Artificial and natural sources, Measurement of intensity: concept of specific emissions.

2.3 Interaction of radiation with matter, Absorption, Scattering, Photoelectric effect, Compton effect, Absorption coefficient, Half-thickness, Calculation of attenuation coefficient for simple materials and components.

2.4 Measurement of ionization and units, Detection of radiation by ionization, Exposure, absorbed dose, equivalent dose, dose intensity, Calculations relating to radiation dosimetry, Principles of detection by means of film, fluorescent material or electronic systems in radiographic testing.

Subject 3 **Equipment — Radiation Sources** **3 h**

3.1 Industrial radiation sources, X-ray generators, Linac, betatrons, Equipment for gamma radiation, Purchase, acceptance, operation and maintenance, Shielding, filtering and collimation.

3.2 Facilities for industrial radiography, Accessories.

Subject 4 **Photographic Recording** **3 h**

4.1 Photographic recording, Film principles and properties, Emulsions/types/characteristic curves/radiographic quality, Types of film for industrial radiography, sensitometric curves, Exposure curves, Lead and Fluorescent screens.

Subject 5 **Work Parameters and Conditions** **5 h**

5.1 Operating parameters and image quality in radiographic testing, radiographic sensitivity.

5.2 Operating techniques for real-time fluoroscopy and radiography, testing sensitivity, fluctuation, and resolution.

5.3 Film processing, equipment, facilities and reagents, Handing and conservation, Special situations, influence of the observations/conditions in defect detection, lighting control reagents brightness requirements, Causes of defective radiographs and correction thereof, Processing defects, Systematic control of radiographic quality.

5.4 Conditions for observing radiographs, Lighting and perceptibility.

Subject 6 **Defectology** **4 h**

6.1 Radiographic indication of defects relation between image and objects, Types of defects and their formation, Casting, welding, heat treatment, forging, lamination, corrosion, etc.

6.2 Discontinuities in radiography, Standard reference radiographs.

Subject 7 **Selection of Techniques** **3 h**

7.1 Influence of the properties of materials, Compound materials, probability of detection according to type, size, position and direction of the defect.

7.2 Exposure technique depending on the geometry and accessibility of the object, Single wall/single image, Double wall/single image, Double wall/double image, Panoramic exposure, Compensation for thickness, Masks, Latitude, Technique, High and low sensitivity techniques.

Subject 8 **Selection of Test Methods According to Standards, etc** **3 h**

8.1 National and International Codes and Standards for radiographic testing, Specifications for radiographic testing.

Subject 9 **Personal Safety and Radiation Profession** **3 h**

9.1 Radiation and its effects, Biological effects of radiation, International regulations and recommendations for radiation protection, Equipment and facilities, Design and calculation of shielding for equipment and facilities, Design of packaging for the transport of radioactive sources, Verification of radiation of leaks from X-ray equipment, Operational procedures, Safety in equipment and facilities for industrial radiography, Maintenance of equipment for scrutiny scanning, Radiation safety conditions for work in the field.

Subject 10 Special Applications 2 h

10.1 Special film techniques, Panoramic exposure, Defect-depth determination techniques, Radiography of radioactive objects.

10.2 Radiography on non-metallic materials (plastics, ceramics, compounds, etc), Low energy radiography.

10.3 Application of radiographic techniques in non-conventional areas, Aeronautics and aerospace, offshore structures and others.

10.4 Radiation gaging, Beta Backscatter Techniques.

Subject 11 Recording of Test and Interpretation Results 2 h

11.1 The recording of test, Test documentation, Evaluation of results and according to standards and application of codes.

Subject 12 Radiography Techniques 1 h

12.1 Neutron Radiography — Principle, Sources, Moderation and Collimation, Detection and Application, Electron and Proton radiography and Auto radiography.

Subject 13 Advances in Radiography 3 h

13.1 Microfocal radiography, Real Time and Digital Radioscopy, Tomography, Image Processing and Enhancement Techniques in radiography.

Subject 14 Quality Assurances and Standardization 2 h

14.1 Basic principles for the application of quality assurance7.

14.2 Organization of quality assurance, Quality manual, Quality control and auditing of quality.

14.3 Management and control of quality assurance documentation, quality control of testing, Reports on testing, Documentation systems, Standardization, Definitions of standardization, Principles of standard writing, Standards, Codes, Specification procedures and their uses, Reports and protocols

Subject 15 Organisation and Administration of NDT 2 h

15.1 Organization and administration of NDT

Safety: (a) Implementation of industrial safety in facilities and equipment and in their operation, (b) Hazards of using toxic and inflammable materials, (c) Materials, accessories and equipment for the protection of persons and facilities.

15.2 Organization: (a) Equipment for work underway, Logistic provisions, (b) Testing on production lines, Flow of materials, Work shifts, Maintenance of equipment and facilities.

15.3 Costs: (a) Investment in equipment, (b) Direct and indirect staff costs, (c) Calculation and analysis of costs and profitability.

15.4 Equipment selection and facility design, Operating procedures and record keeping.

Subject 16 Qualification and Certification of NDT Personnel 1 h

16.1 Qualification and certification of personnel for NDT, National standards for the qualification and certification of personnel, Training of personnel for NDT organization of courses and training in NDT methods, Code of ethics.

Inspection Method: Ultrasonic Method (Summary)

Sl No.	Subject	Hours of Training		
		Level I	Level II	Level III
(1)	(2)	(3)	(4)	(5)
i)	General knowledge	4	4	—
ii)	Terminology, physical principles and fundamentals of ultrasonic	8	6	5
iii)	Testing techniques and their limitations	4	6	5
iv)	Equipment and accessories	4	4	5
v)	Calibration of the testing system	8	6	6
vi)	Specific applications	4	6	4
vii)	Codes, standards, specifications, procedures	4	3	4
viii)	Recording and evaluation of results	4	3	2
ix)	Special techniques	—	2	4
x)	Quality assurance	—	—	2
xi)	Organization and administration of NDT	—	—	1
xii)	Qualification and certification of NDT personnel	—	—	1
	Total	**40**	**40**	**40**

Inspection Method : Ultrasonic Testing Level I

Subject 1	**General Knowledge**	**4 h**

1.1 Non-destructive testing of materials, Definitions reasons for using NDT, description and field of application of the most common methods, Comparison between methods.

1.2 Materials, discontinuities, defects, properties of material, properties of metal.

1.3 Defects originating from melting, pouring, cooling. Processing defects from welding, forging, rolling, hear treatment, machining, plating, etc, service defects due to overload, fatigue, corrosion, brittle, fracture, and others.

Subject 2	**Terminology, Physical Principles and Fundamentals and Ultrasonics**	**8 h**

2.1 Properties of sound and propagation of waves Concepts relating to frequency, amplitude, wave length and speed of propagation.

2.2 Acoustic impedance, Influence of wave type of the test method, longitudinal waves and transverse waves, Surface waves and Lamb waves.

2.3 Reflection and refraction, Mode conversion, Attenuation.

2.4 Energy transfer from one medium to another generation of ultrasonic waves, Energy losses in different media.

2.5 Piezoelectric effect, Characteristics and types of crystals, Sonic Field: Influence of speed of sound and transducer size.

2.6 Types of probe, Normal, Transmitter receiver (T-R) Angular.

2.7 The Sonic path, near field far field divergence.

Subject 3	Testing Techniques and their Limitations	4 h

3.1 Pulse echo technique: By direct contact, by immersion with transmitter receiver sensors.

3.2 Through — Transmission Technique, Resonance Technique.

3.3 Methods of coupling, testing with automatic system and on production line.

Subject 4	Equipment and Accessories	4 h

4.1 Description of the basic testing equipment with display of the information in a representation.

4.2 Analog and digital equipment for thickness measurements, Monitors, Functions and Use.

Subject 5	Calibration of the Testing System	8 h

5.1 Remote calibration for normal single and double crystal sensors (Emitter-collector), Angular sensors of transverse waves, Sonic path calibration, Projected distance, shortened projected distance, Checking the calibration – consideration of differences in speeds of propagation between calibration unit and test piece.

Subject 6	Specific Applications	4 h

6.1 Testing of simple geometries. Examination of sheets, Examination of billets, Weldments, pipes, forgings, Thickness measurements, Influences of material type, Geometry, Influence of surface conditions and Detection of corrosion.

Subject 7	Codes, Standards, Specification and Procedures	4 h

7.1 General knowledge, Codes and standards, General knowledge of specifications and procedures, Performance of tests in accordance with written instructions.

Subject 8	Recording and Evaluation of Results	4 h

8.1 Recording of the test results, Position of defects echo amplitude, defect dimensions (average value length)

Ultrasonic Testing, Level I — Practicals

a) Equipment familiarization,
b) Calibration of equipment using V1 and V2 blocks,
c) Calibration of equipment using area amplitude, distance amplitude reference blocks,
d) Use of DAC Curves,
e) Testing of simple geometries and welded samples,
f) Testing according to written instructions, and
g) Recording of test results.

Inspection Method : Ultrasonic Testing
Level II

Subject 1	General Knowledge	4 h

1.1 Basic principles of NDT, Definitions, Methodology of applications, Areas of application of common methods, Range and limitations of common methods.

1.2 Materials and defects, Structure of metals and alloys, Physical and mechanical properties of metallic materials, Discontinuities and defects in metallic materials.

1.3 Processing defects, primary processes and related defects, Manufacturing processes and related defects.

1.4 Materials in service, Behaviour of materials in service, Service conditions leading to defects and failures: (a) Corrosion, (b) Fatigue, (c) Wear, (d) Overload, (e) Brittle fracture, Concepts of rupture development in metals.

1.5 Quality and standardization, Definition of quality, quality control, standardization. Development of a quality system, Examination, testing and inspection, Standards, codes, specifications and procedures, Reports, records and protocols.

Subject 2 Terminology, Physical Principles and Fundamentals of Ultrasonics 6 h

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2.1 The nature of ultrasonic waves, Characteristics of wave propagation, Frequency, Wave length, Velocity, Acoustic impedances, Acoustic pressure, Acoustic energy, Acoustic intensity, Amplitude.

2.2 Types of ultrasonic waves and their applications, Longitudinal wave, Transverse wave, Surface wave, Lamb wave.

2.3 Behaviour of ultrasonic waves, Normal incidence, Angular incidence, Reflection and refraction, Mode conversion.

2.4 Transfer of energy from one medium to another, Generation of ultrasonic waves. Energy losses in various media.

2.5 Piezoelectric and magnetostrictive effect on crystal.

2.6 Characteristics of sound beam. Far field and near field. Influence and sound velocity and transducer size, Field divergence.

2.7 Attenuation of sound, Cause and effect Principles of measurement.

Subject 3 Testing Techniques and Their Limitations 6 h

3.1 Test methods, Resonance method, Through-Transmission method, Pulse echo method, Automatic and semi-automatic method.

3.2 Sensors — Normal incidence, Angular incidence sensors, Special sensors.

3.3 Techniques: Tandem techniques, Focussed sensor technique, Double crystal sensor technique, Surface wave sensor technique, Immersion technique.

3.4 Limitations in the application of the ultrasonic test method.

Subject 4 Equipment and Accessories 4 h

4.1 Construction and mode of operation of ultrasonic equipment. Functions of the electronic elements in a typical instrument Types of instrumentation: (a) Portable, (b) Laboratory, (c) Digital, and (d) Automated installations.

4.2 Characteristics of equipment and system controls, Properties of vertical and horizontal amplifiers. Correlation between resolving power and frequency transmitting power, damping linearity, Saturation and amplifier threshold signal presentation. Echo-amplitude and its control. A-scan, B-scan, C-scan, Correlation of digital and analogue signals.

4.3 Recording Instrumentation, Automatic monitors, Computer interfacing, Recorders, printers and colour markers.

Subject 5 Calibration of the Testing System 6 h

5.1 Calibration of equipment. Horizontal linearity, Vertical linearity, Verification of the sensor, Calibration blocks V1 and V2, Sensor sensitivity, Sensor resolution, Verification of angular sensor, Calibration in curved work pieces, Construction of DAC, DGS method, Coupling medium.

Subject 6 Specific Applications 6 h

6.1 Methods of examination, Cast work pieces, Welded work pieces, Components and systems, Austenitic materials, Forged work pieces.

Subject 7	Codes, Standards, Specifications and Procedures	3 h

7.1 Codes, standards and specifications specifically related to ultrasonic testing. Testing procedures, Selection of equipment, Position and direction of scan, Calibration.

Subject 8	Recording and Evolution of Results	3 h

8.1 Response of equipment of various types of defect, Evaluation of discontinuities in accordance with specifications, standards and codes, Recording and reporting the results of a test.

Subject 9	Special Techniques	2 h

9.1 Special inspection problem and technique used to solve them.

9.2 TOFD.

9.3 Awareness.

Ultrasonic Testing, Level II — Practicals

a) Equipment familiarization,
b) Calibration of equipment using V1 and V2 blocks,
c) Preparation of DAC Curves,
d) Use of DGS diagram,
e) Inspection of welded samples,
f) Inspection of castings and forgings,
g) Inspection of components,
h) Examination according to given procedure,
j) Report preparation,
k) Evaluation of discontinuities as per the given codes,
m) Recording and interpretation of results, and
n) Special techniques.

Inspection Method : Ultrasonic Testing
Level III

Subject 1	General Knowledge (covered in Basics)	

Subject 2	Terminology, Physical Principles and Fundamentals of Ultrasonics	5 h

2.1 Nature of ultrasonic waves.

2.2 Characteristics of ultrasonic wave propagation, Frequency, Wavelength, Velocity, Acoustic impedance, Acoustic energy, Acoustic intensity, Amplitude.

2.3 Types of Ultrasonic waves and their applications: (a) Longitudinal wave, (b) Transverse wave, (c) Surface wave, (d) Lamb wave.

2.4 Behaviour of Ultrasonic waves: (a) Normal incidence, (b) Angular incidence, (c) Reflection and refraction, (d) Methods of conversion.

2.5 Transfer of energy from one medium to another. Generation of ultrasonic waves; energy losses in various media.

2.6 Piezoelectric effect and magnetostrictive effect in crystals.

2.7 Far field and near field, Influence of the speed of sound and the size of the transducer, Divergence of the field.

2.8 Attenuation of sound: Cause, effect, and principles of measurement.

Subject 3	Testing Techniques and Their Limitations	5 h

3.1 Testing methods: Resonance method, Transmission method, Pulse-echo method. Automatic and semi-automatic methods.

3.2 Sensors: Normal-incidence sensors, Angular incidence sensors and Special sensors.

3.3 Techniques:.Tandem technique, Focalized sensor technique, Double crystal sensor technique, Surface wave sensor technique, Immersion technique.

3.4 Limitations to the application of ultrasonic testing.

Subject 4	Equipments and Accessories	5 h

4.1 Construction and mode of operation of ultrasonic equipment.

4.2 Types of instrumentation: (a) Portable, (b) Laboratory, (c) Digital, (d) Automated installations.

4.3 Characteristics of equipment and system controls, properties of vertical and horizontal amplifiers, Correlation between resolving power and frequency, transmitting power, damping, Linearity, Saturation and amplifier threshold.

4.4 Signal Presentation: Echo amplitude and its control, A-scan, B-scan, C-scan, and Correlation of digital and analogue signals.

4.5 Recording Instrumentation: Automatic monitors, Computer interfacing recorders, printers and colour markers.

Subject 5	Calibration of the Testing Systems	6 h

5.1 Calibration and adjustment of the equipment, Instrumentation, Accessories, Joint control of calibration.

5.2 Calibration of the sensitivity of the test. Different geometric conditions. Design and preparation of calibration units, various calibration criteria (DAC, DGS, etc) and selection of suitable reflectors, exact measurement of speed of propagation, Use of interferometers.

5.3 Transmission of ultrasonic energy across the surface being explored Condition of surface, curvature, Precaution against excitation. Crystal diameter and coupling medium.

Subject 6	Specific Applications	4 h

6.1 Methods of examination.

6.2 Cast material.

6.3 Welded pieces.

6.4 Components and systems.

6.5 Austenitic material.

6.6 Forged pieces.

Subject 7	Codes, Standards, Specifications and Procedures	4 h

7.1 Examination specifications: Function and design engineering. Design and building codes.

7.2 Standards for Ultrasonic testing : Specific standards for testing with Ultrasonic interpretation of specification, codes and standards.

7.3 Test procedures: Drafting of test procedures, General and specific procedures.

Subject 8 **Recording and Evaluation of Results** **2 h**

8.1 Response of the equipment to the various types of defect, Evaluation of discontinuities in accordance with specification, standards and codes, Recording and reporting on the test.

Subject 9 **Special Techniques** **4 h**

9.1 Special techniques: Ultrasonic holography, Ultrasonic spectroscopy, Automated and semi-automated testing techniques. Special techniques for data processing, imaging techniques (P-scan, ISO-scan, D-scan, T-scan).

Subject 10 **Quality Assurances and Standardization** **2 h**

10.1 Quality assurance: Basic principles for the application of quality assurance. Organization of quality assurance, Quality manual, Quality control, Auditing of quality, Management and control of quality assurance documentation, Quality control of testing, Reports on testing documentation systems.

10.2 Standardization: Definition of standardization, Principles of standards writing, Standards, Codes, Specifications and Procedures and their uses, Reports and protocols.

Subject 11 **Organization and Administration of NDT** **1 h**

11.1 Organization and administration of NDT Safety.

a) Implementation of industrial safety in facilities and equipment and in their operation.
b) Hazards of using toxic and inflammable materials.
c) Materials, accessories and equipment for the protection of persons and facilities.

11.2 Organization: (a) Equipment for work under way, Logistic provisions; (b) Testing on production lines, Flow of materials, Work shifts, Maintenance of equipment and facilities.

11.3 Costs: (a) Investment in equipment, (b) Direct and indirect staff costs, (c) Calculation and analysis of costs and profitability.

11.4 Equipment selection, facility design, Operating procedures and record keeping.

Subject 12 **Qualifications and Certification of NDT Personnel** **1 h**

12.1 Qualification and certification of personnel for NDT, National standards for the qualification and certification of personnel, Training of personnel for NDT. Organization of courses and training in NDT methods, Code of ethics.

Inspection Method : Acoustic Emission Testing
(Summary)

Sl No.	Subject	Hours of Training		
		Level I	Level II	Level III
(1)	(2)	(3)	(4)	(5)
i)	General knowledge	4	4	—
ii)	Principles of acoustic emission testing	6	10	4
iii)	Detection of acoustic emission	6	10	4
iv)	Instrumentation and signal processing	8	10	6
v)	Acoustic emission test procedures	6	12	6
vi)	Application of acoustic emission testing	6	12	4
vii)	Codes, standards and procedures	2	4	4
viii)	Safety and health	2	2	2

ix)	Quality assurance and standardization	—	—	2
x)	Organization and administration of NDT safety	—	—	2
xi)	Qualification and certification of NDT personnel	—	—	1
	Total	**40**	**64**	**40**

Inspection Method : Acoustic Emission Testing
Level I

Subject 1 General Knowledge 4 h

1.1 Non-destructive testing of materials, Definitions reasons for using NDT, description and field of application of the most common methods, Comparison between methods.

1.2 Materials, discontinuities, defects, properties of material, properties of metal.

1.3 Defects originating from melting, pouring, cooling. Processing defects from welding, forging, rolling, hear treatment, machining, plating, etc. service defects due to overload, fatigue, corrosion, brittle, fracture, and others.

Subject 2 Principles of Acoustic Emission Testing 4 h

2.1 Characteristics of acoustic emission, the phenomena of acoustic emission, types of acoustic emission, emission levels and frequencies.

2.2 Sources of Acoustic Emission, sources in Crystalline materials — introduction, Sources in Non-metals — introduction, sources in composite — introduction, other sources of acoustic emission — (a) Liquid/gas leakage, (b) Oxide and scale cracking, (c) Slag cracking, (d) Frictional sources, (e) Liquefaction and solidification, (f) Loose particles and loose parts, (g) Fluids and non-solids, (h) Crack closure.

2.3 Wave propagation — Introduction, acoustic waves, attenuation of waves, average velocity in materials.

2.4 Kaiser effect and Felicity ratio, in metals, in composits.

Subject 3 Detection of Acoustic Emission 6 h

3.1 Sensors' definition and types of sensors, Principles of operation, Construction.

3.2 Sensor attachment, coupling and bonds, attachment devices and wave-guides.

3.3 Sensor preamplifier transmission cables, types of cables, noise susceptibility, impedance matching, connectors, integral electronic sensors.

Subject 4 Instrumentation and Signal Processing 8 h

4.1 Conditioning of acoustic emission signals, preamplifiers, amplifiers, filters, gain and threshold settings.

4.2 Processing of acoustic emission signals, waveform characteristics (Time and frequency), discrimination techniques, distribution techniques, location techniques.

4.3 Data display and recording techniques, auto indicators, X-Y and strip chart recording, digital counters and processors, oscilloscopes, others.

4.4 Acoustic emission test systems, Single channel systems, multi-channel systems, and dedicated industrial systems.

Subject 5	**Acoustic Emission Test Procedures**	**6 h**

5.1 Calibration of test equipment, calibration signal generation techniques, adjustment of equipment controls, discrimination technique adjustments.

5.2 Data display and interpretation of results, selection and display mode, comparison with calibration signal, source verification and evaluation by other NDT techniques.

5.3 Background Noise-Identification and Elimination, Types of Noise, General Noise Elimination Methods: (a) Spatial filtering, (b) Parametric filtering, (c) Use of attenuating materials, (d) Pseudo sources.

5.4 Test report.

Subject 6	**Application of Acoustic Emission Testing**	**6 h**

6.1 Fundamental studies — Introduction.

6.2 Source detection and location.

6.3 Other applications-pressure vessels (metals), Wood and wooden structures, rock mechanics, civil structures: (a) Bridges, (b) Buildings, (c) Dams, (d) Buried Pipeline, (e) Slopes, (f) Cavities, (g) Mines, leak detection, composite materials and structures, refractory structures, machinery analysis, microseismology, acoustic signature analysis.

6.4 Conditions that cause poor accoustic emission applicability.

Subject 7	**Codes, Standards and Procedures**	**2 h**

7.1 Guide — type standards (glossaries, calibration etc).

7.2 Standardized/codified accoustic emission test procedures.

7.3 User — developed test procedures.

Subject 8	**Safety and Health**	**2 h**

8.1 Hazards associated with structural failure during test.

8.2 Other hazards associated with accoustic emission testing.

8.3 Importance of local regulations.

Inspection Method — Acoustic Emission Testing
Level II

Subject 1	**General Knowledge**	**4 h**

1.1 Basic principles of NDT, Definitions, methodology of applications, Areas of application of common methods, Range and limitations of common methods.

1.2 Materials and defects, Structure of metals and alloys, Physical and mechanical properties of metallic materials, Discontinuities and defects in metallic materials.

1.3 Processing defects, primary processes and related defects, Manufacturing processes and related defects.

1.4 Materials in service, Behaviour of materials in service, Service conditions leading to defects and failures — (a) Corrosion, (b) Fatigue, (c) Wear, (d) Overload, (e) Brittle fracture, Concepts of rupture development in metals.

1.5 Quality and standardization, Definition of quality, quality control, standardization. Development of a quality system, Examination, testing and inspection, Standards, Codes, Specifications and Procedures, Reports, records and protocols.

Subject 2 Principles of Acoustic Emission Testing 10 h

2.1 Characteristics of acoustic emission — an overview of acoustic emission testing, types of acoustic emission, emission levels and frequencies.

2.2 Sources of acoustic emission — Sources in crystalline materials.

(a) Dislocations — plastic deformation, (b) Phase transformations, (c) Deformation twinning, (d) Non-metallic — inclusions, (e) Subcritical crackgrowth: (1) Subcritical crack growth under increasing load, (2) Ductile tearing under increasing load, (3) Fatigue crack nucleation and growth, (4) Hydrogen embrittlement cracking, (5) Stress corrosion cracking, Sources in non-metals, (a) Microcracking, (b) Gross cracking, (c) Crazing, (d) Other sources in non-metals, Sources in composites, (a) Fibre fracture, (b) Matrix cracking, (c) Delamination and disbanding, other sources: (a) Liquid/gas leakage, (b) Oxide and scale cracking, (c) Slag cracking, (d) Frictional sources (e) Liquefaction and solidification, (f) Loose particles and loose parts, (g) Fluids and non-solids, (h) Crack closure.

2.3 Wave propagation — modes of propagation, mode conversion, reflection and refraction, attenuation, wave velocity in materials, specimen geometry effects.

2.4 Kaiser effect and Felicity Ratio in metals, in composites, in other materials.

Subject 3 Detection of Acoustic Emission 10 h

3.1 Detection processes piezoelectricity, capacitance, laser, etc.

3.2 Sensors — Construction, conversion efficiencies, calibration (sensitivity curve).

3.3 Sensor attachment — Couplants and bonds, attachment devices, waveguides.

3.4 Sensor — Preamplifier transmission cables — Cable types, noise susceptibility, impedance matching, connectors, Integral electronic sensors.

Subject 4 Instrumentation and Signal Processing 10 h

4.1 Signal conditioning — Preamplifiers, amplifiers, filters, units of gain measurement.

4.2 Signal processing — Waveform characteristics.

(a) Amplitude analysis, (b) Pulse duration analysis, (c) Rise time analysis, (d) Event and event rate processing, discrimination techniques, distribution techniques, location techniques.

4.3 Data display and recording techniques — Audio indicators, X-Y and strip chart recording, digital counters and processors, oscilloscopes, Magnetic recorders, Other techniques.

4.4 Acoustic emission test systems — Single channel systems, Multi-channel systems, dedicated industrial systems.

Subject 5 Acoustic Emission Test Procedures 12 h

5.1 Factors affecting test equipment selection — Material to be tested, environment, size and shape of test part, information desired, location and nature of emission.

5.2 Calibration of test equipment — Calibration signal generation techniques, adjustment of equipment controls, discrimination technique adjustments, recognition of severe attenuation ear failure.

5.3 Loading procedures — Type of loading, maximum test load, load holds, repeated and programmed loadings, rate of loading.

5.4 Special test procedures — High temperature/low temperature tests, interrupted tests (including cyclic fatigue), long-term tests, tests in high noise environments.

5.5 Data display and interpretation — Selection of display mode, source classification and evaluation, comparison with calibration signals, source evaluation by other NDT methods.

5.6 Background Noise — Identification and elimination — Types of noise — General noise elimination methods —

(a) Spatial filtering, (b) Parametric filtering, (c) Use of attenuating materials, (d) Pseudo sources.

5.7 Test report.

Subject 6 — Applications of Acoustic Emission Testing — 12 h

6.1 Laboratory studies material characterization) — Crack growth and fracture mechanics, environmentally assisted cracking, stress corrosion, hydrogen embitterment, dislocation movement, phase transformation and Phase stability, creep, residual stress,corrosion, fatigue, rupture, ductile/brittle transition.

6.2 Source detection and location — Aerospace vehicles, pressure vessels and piping, nuclear reactors, weld monitoring, trusses and beams.

6.3 Other applications — Pressure vessels (metal), Storage tanks (metal), Pressure vessels/Storage tanks (composite), wood and wooden structures, rock mechanics, civil structures (a) Bridges, (b) Buildings, (c) Dams, (d) Buried pipeline, (e) Slopes, (f) Cavities, (g) Mines, leak detection, refractory structures, machinery analysis, microseismology, acoustic signature analysis.

6.4 Conditions that cause poor accoustic emission applicability.

Subject 7 — Codes, Standards and Procedures — 4 h

7.1 Guide — type standards (glossaries, calibration etc).

7.2 Standardized/codified accoustic emission test procedure.

7.3 User — developed test procedures.

7.4 Societies active in accoustic emission.

Subject 8 — Safety and Health — 2 h

8.1 Hazards associated with structural failure during test.

8.2 Other hazards associated with accoustic emission testing.

8.3 Importance of local regulations.

Inspection Method : Acoustic Emission Testing
Level III

Subject 1 — General Knowledge (Covered in Basics)

Subject 2 — Principles of Acoustic Emission testing — 4 h

2.1 Characteristic of acoustic emission — An overview of acoustic emission testing, Types of acoustic emission,. Emission levels and characteristics, Math review (exponents, logarithms, metric units, and conversions.

2.2 Sources of acoustic emission: Breadband nature of source spectra, Emission/signal levels, and units of amplitude measurement.

Sources in crystalline materials : (a) Dislocations — plastic deformation, (b) Phase transformations, (c) Deformation twining, (d) Non-metallic — inclusions, (e) Subcritical crack growth : (1) Subcritical crack growth under increasing load, (2) Ductile tearing under increasing load, (3) Fatigue crack nucleation and growth, (4) Hydrogen embrittlement cracking, (5) Stress corrosion cracking.

Sources in non-metals : (a) Microcracking, (b) Gross cracking, (c) Crazing, (d) Other sources in non-metals.

Sources in composites: (a) Fibre fracture, (b) Matrix cracking, (c) Delamination and disbanding, (d) Fiber pullout, relaxation, (e) Friction.

Other sources: (a) Liquid/gas leakage, (b) Oxide and scale cracking, (c) Slag cracking, (d) Frictional sources, (e) Liquefaction and solidification, (f) Loose particles and loose parts, (g) Fluids and non-solids, (h) Crack closure.

2.3 Wave propagation: Near field impulse response, Modes of propagation, Mode conversion, reflection and refraction, Attenuation, Wave velocity in materials, Specimen geometry effects, Anisotropic propagation in composits.

2.5 Kaiser effect and Felicity Ratio : In metals, In composits, In other materials.

Subject 3 Detection of Acoustic Emission 4 h

3.1 Detection processes (piezoelectricity, capacitance, laser, etc).

3.2 Sensors: Construction — Conversion efficiencies, Calibration (sensitivity curve), Reciprocity.

3.3 Sensor attachment : Couplants and bonds, Attachment devices, Waveguides.

3.4 Simulated AE Sources : Hsu-Nielsen source (Lead break), Piezoelectric sensors in associated electronics, Gas jet, Other devices.

3.5 Sensor — Preamplifier transmission cables : Cable types, Noise susceptibility, Impedance matching, Connectors, Integral electronic sensors.

Subject 4 Instrumentation and Signal Processing 6 h

4.1 Signal conditioning — Preamplifiers, Amplifiers, Filters, Units of gain measurement.

4.2 Dignal processing — Waveform characteristics: (a) Amplitude analysis, (b) Pulse duration analysis, (c) Filters, (d) Event and event rate processing, Discrimination techniques, Distribution techniques, Location techniques

4.3. Data display and recording techniques — Audio indicators, X-Y and strip chart recording, Digital counters and processors, Oscilloscopes, Other techniques.

4.4 Acoustic emission test systems — Single channel systems, Multi-channel systems, Dedicated industrial systems.

Subject 5 Acoustic Emission Test Procedures 6h

5.1 Calibration of test equipment — Calibration signal generation techniques, Adjustment of equipment controls, Discrimination techniques adjustments, Recognition of severe attenuation near failure.

5.2 Special test procedures — High temperature/low temperature tests, Interrupted tests (including cyclic fatigue), Long-term tests, Tests in high noise environments.

5.3 Data display and interpretation — Selection of display mode, Source classification and evaluation, Comparison with calibration signals, Source evaluation by other NDT methods.

5.4. Background Noise — Identification and Elimination: Types of noise, General Noise Elimination Methods: (a) Spatial filtering, (b) Parametric filtering, (c) Use of attenuating materials, (d) Pseudo sources.

5.5 Test report.

Subject 6 Applications of Acoustic Emission Testing 4 h

6.1 Laboratory studies (material characterization) — Crack growth and Fracture mechanics, Environmentally assisted cracking, Stress corrosion, Hydrogen embrittlement, Dislocation movement, Phase transformation and phase stability, Creep, Residual stress, Corrosion, Fatigue, Rupture, Ductile/ brittle transition.

6.2 Source detection and location — Aerospace vehicles, Pressure vessels and piping, Nuclear reactors, Weld monitoring, Trusses and beams.

6.3 Other applications: Pressure vessels (metal), Storage tanks (metal), Pressure vessels /Storage tanks (composite), Wood and wooden structures, Rock mechanics, Civil structures: (a) Bridges, (b) Buildings, (c) Dams, (d) Buried pipeline, (e) Slopes, (f) Cavities, (g) Mines, Leak detection, Refractory structures, Machinery analysis, Micro-seismology, Acoustic signature analysis.

6.4 Conditions that cause poor accoustic emission applicability.

Subject 7	Codes, Standards and Procedures	4 h

7.1 Guide-type standards (glossaries, calibration, etc).

7.2 Standardized/codified accoustic emission test procedures.

7.3 User-developed test procedures.

7.4 Societies active in accoustic emission.

Subject 8	Safety and Health	2 h

8.1 Hazards associated with structural failure during test.

8.2 Other hazards associated with accoustic emission testing.

8.3 Importance of local regulations.

Subject 9	Quality Assurance and Standardization	2 h

9.1 Quality assurance; basic principles for the application of quality assurance — Organization of quality assurance — Quality manual, quality control; auditing of quality. Management and control of quality assurance documentation, quality control of testing, Reports on testing, documentation system.

9.2 Standardization — Definition of standardization — Principles of standard writing, standards, codes; specifications and procedures, their uses — Reports and protocols.

Subject 10	Organization and Administration of NDT Safety	2 h

10.1 Organization and administration of NDT safety: (a) Implementation of industrials safety in facilities and their operation, (b) Hazards of using toxic and inflammable materials, (c) Materials, accessories and equipment for the protection of personnel and facilities.

10.2 Organization — Equipment for work under way, logistic provision, testing on production lines, Flow of materials, Work shifts, Maintenance of equipment and facilities.

10.3 Costs — Investment in equipment, Direct and indirect staff costs, Calculation and analysis of costs and profitability.

10.4 Equipment selection and facility design — Operation procedures and record keeping.

Subject 11	Qualification and Certification of NDT Personnel	1 h

11.1 Qualification and certification of Personnel for NDT — National standards for the qualification and certification of personnel — Training of personnel for NDT — Organization of courses and training in NDT methods — Code of ethics.

Inspection Method : Vibration Analysis Testing
(Summary)

Sl No.	Subject	Hours of Training		
		Level I	Level II	Level III
(1)	(2)	(3)	(4)	(5)
i)	General knowledge	4	4	—
ii)	Vibration theory	2	8	4
iii)	Machinery basics	4	10	6
iv)	Vibration measurement and analysis	6	20	8
v)	Problem identification from analysis	4	20	8
vi)	Other NDT techniques for machinery	—	—	4
vii)	General	2	6	5
viii)	Quality assurances and standardization	—	—	2
ix)	Organisation and administration of NDT	—	—	2
x)	Qualification and certification of NDT personnel	—	—	1
	Total	**24**	**80**	**40**

Inspection Method : Vibration Analysis Testing
Level I

Subject 1	General Knowledge	4 h

1.1 Non-destructive testing of materials, Definitions, reasons for using NDT, Description and field of application of the most common methods, Comparison between methods.

1.2 Materials, discontinuities, defects, properties of material, properties of metal.

1.3 Defects originating from melting, pouring, cooling. Processing defects from welding, forging, rolling, hear treatment, machining, plating, etc, service defects due to overload, fatigue, corrosion, brittle, fracture, and others.

Subject 2	Vibration Theory	2 h

2.1 Simple harmonic motion.

2.2 Mass-spring system.

2.3 Damping.

2.4 Free and forced vibrations.

2.5 Resonance.

2.6 Complex vibration and frequency spectrum.

2.7 Definition of terms — Displacement, velocity and acceleration, RMS, peak, peak-peak and average values.

Subject 3	Machinery Basics	4 h

3.1 Rotating machines.

3.2 Reciprocating machines.

3.3 Machine components — Bearings, Couplings, Gears, Rotor assembly, Impeller.

3.4 Machine orientation.

3.5 Cause of vibration — Unbalance, Misalignment, Bearing defects, Coupling defects, Poor foundation, Electrical defects.

3.6 Undesirable effects of vibration.

Subject 4	**Vibration Measurement and Analysis**	**5 h**

4.1 Units.

4.2 Orientation.

4.3 Sensors — Displacement, Velocity, Acceleration.

4.4 Selection and limitations.

4.5 Measurement location and mounting.

4.6 Readout instruments — Selection and limitations.

4.7 Vibration severity standards.

4.8 Data presentation.

4.9 Frequency analysis — Principles.

Subject 5	**Problem Identification from Analysis**	**5 h**

5.1 Cause (*versus*) Frequency component.

5.2 Baseline data comparison.

5.3 Presentation of data.

Subject 6	**Other NDT Techniques for Machinery Diagnostics**	**2 h**

6.1 Shock pulse meter.

6.2 Noise measurement.

6.3 Acoustic emission — Principle, Transducers, Electronic hardware, Application examples.

Subject 7	**General**	**2 h**

7.1 Predictive maintenance.

7.2 Standards on vibration.

7.3 Safety and health.

7.4 Effects of vibrations on human beings.

7.5 Standards on noise limits.

Inspection Method : Vibrational Analysis Testing
Level II

Subject 1	General Knowledge	4 h

1.1 Basic principles of NDT, Definitions, methodology of applications, Areas of application of common methods, Range and limitations of common methods.

1.2 Materials and defects, Structure of metals and alloys, Physical and mechanical properties of metallic materials, Discontinuities and defects in metallic materials.

1.3 Processing defects, Primary processes and related defects, Manufacturing processes and related defects.

1.4 Materials in service, Behaviour of materials in service, Service conditions leading to defects and failures: (a) Corrosion, (b) Fatigue, (c) Wear, (d) Overload, (e) Brittle fracture, Concepts of rupture development in metals.

1.5 Quality and standardization, Definition of quality, quality control standardization. Development of a quality system, Examination, testing and inspection, Standards, codes, specifications and procedures, Reports, records and protocols.

Subject 2	Vibration Theory	8 h

2.1 Mass-spring system.

2.2 Degrees of freedom.

2.3 Transmissibility.

2.4 Vibration isolation.

2.5 Damping.

2.6 Torsional vibrations.

2.7 Shock.

Subject 3	Machinery Basics	10 h

3.1 Rotary machinery dynamics.

3.2 Reciprocating machinery dynamics.

3.3 Shaft whirl.

3.4 Static and dynamic unbalance.

3.5 Rigid and flexible rotors.

3.6 Bearing types.

3.7 Coupling types.

3.8 Different sources of vibration.

3.9 Foundation types.

Subject 4	Vibration Measurement and Analysis	20 h

4.1 Units and parameters.

4.2 Seismic transducers.

4.3 Operating principle of sensors — Contact and non-contact displacement sensors, Absolute velocity sensors, Accelerometers, Introduction to strain gages.

4.4 Sensor specification — Sensitivity, Frequency response, Mounting methods, Dynamic range, Limitations.

4.5 Sensor selection.

4.6 Readout instrumentation.

4.7 Data presentation.

4.8 Vibration severity charts.

4.9 Vibration analysis — Fourier transform, Analog (*versus*) Digital analysis, Filter characteristics, Linear and log display.

4.10 Digital analysis — Sampling theorem, Aliasing error, Window functions, Averaging, Resolution, Zoom function, Modulation and side bands.

4.11 Phase measurement.

4.12 Statistical analysis — Probability density function, Kurtosis and skewness, Auto-correlation function.

Subject 5	Problem Identification from Analysis	20 h

5.1 Cause (*versus*) Frequency component.

5.2 Baseline data comparison.

5.3 Presentation of data.

Subject 6	Other NDT Techniques for Machinery Diagnostics	6 h

6.1 Shock pulse meter.

6.2 Noise measurement.

6.3 Accoustic emission — Principle, Transducers, Electronic hardware, Application examples.

Subject 7	General	12 h

7.1 Predictive maintenance.

7.2 Standards on vibration.

7.3 Safety and health.

7.4 Effects of vibrations on human beings.

7.5 Standards on noise limits.

Inspection Method : Vibration Analysis Testing
Level III

Subject 1	General Knowledge (covered in Basics)	

Subject 2	Vibration Theory	4 h

2.1 Recap of level II topics — Random vibration, transient vibrations, Non-linear systems, Vibration in other plant equipment — Heat exchanger tubes, Valves, pipelines, structures, introduction to cavitation, Valves, Pipelines, Structures, Introduction to cavitation, Vibration dampers.

2.2 Mode shapes of tubes, shaft etc.

Subject 3	Machinery Basics	6 h

3.1 Recap of level II topics.

3.2 Multi-bearing systems.

3.3 Critical speed.

Subject 4	**Vibration Measurement and Analysis**	**8 h**

4.1 Recap of level II topics.

4.2 Calibration of sensors.

4.3 Laser vibrometer.

4.4 Exciters.

4.5 Calibration of electronic hardware.

4.6 Dual channel analysis — Correlation function, Cross spectrum, Coherence function, Cause-effect relation, Application examples.

4.7 Torsional vibration measurement.

4.8 Natural frequency measurement.

4.9 Phase analysis.

4.10 Shaft orbit plot measurement.

4.11 Order tracking.

4.12 Time synchronous analysis.

4.13 Cepstrum analysis.

4.14 Modal measurements.

4.15 Presentation of data to management.

Subject 5	**Problem Identification from Analysis**	**8 h**

5.1 Recap of level II topics.

5.2 Remedial measures.

5.3 On-line monitoring.

5.4 Influence of operating parameters.

5.5 *In-situ* balancing techniques.

Subject 6	**Other NDT Techniques for Machinery Diagnostics**	**4 h**

6.1 Shock pulse meter.

6.2 Noise measurement.

6.3 Accoustic emission — Principle, Transducers, Electronic hardware, Application examples.

Subject 7	**General**	**5 h**

7.1 Review of machinery vibration standards.

7.2 TEMA Standard — Heat exchangers.

7.3 How to plan a comprehensive vibration measurement system.

7.4 Qualification and certification of NDT personnel.

7.5 Balancing quality criteria.

Subject 8 **Quality Assurance and Standardization** **2 h**

8.1 Quality assurance; basic principles for the application of quality assurance — Organization of quality assurance — Quality manual, quality control; auditing of quality. Management and control of quality assurance documentation, quality control of testing, Reports on testing, documentation system.

8.2 Standardization — Definition of standardization, Principles of standard writing, Standards, Codes, Specifications and procedures, their uses — Reports and protocols.

Subject 9 **Organization and Administration of NDT Safety** **2 h**

9.1 Organization and administration of NDT Safety (a) Implementation of industrials safety in facilities and their operation, (b) Hazards of using toxic and inflammable materials, (c) Materials, accessories and equipment for the protection of personnel and facilities.

9.2 Organization-equipment for work under way, logistic provision, testing on production lines, Flow of materials, Work shifts, Maintenance of equipment and facilities.

9.3 Costs — Investment in equipment, Direct and indirect staff costs, Calculation and analysis of costs and profitability.

9.4 Equipment selection and facility design — Operation procedures and record keeping.

Subject 10 **Qualification and Certification of NDT Personnel** **1 h**

10.1 Qualification and certification of personnel for NDT — National standards for the qualification and certification of personnel — Training of personnel for NDT — Organization of courses and training in NDT methods — Code of ethics.

Inspection Method : Visual Testing
(Summary)

Sl No.	Subject	Hours of Training		
		Level I	Level II	Level III
(1)	(2)	(3)	(4)	(5)
i)	General knowledge	4	4	—
ii)	Fundamentals of optics	2	2	2
iii)	Vision	1	2	2
iv)	Material characteristics and attributes	1	1	1
v)	Aids to visual testing	3	4	3
vi)	Applications	2	4	3
vii)	Codes, standards and personnel certification	1	2	2
viii)	Evaluation, interpretation and recording	1	2	2
ix)	Safety in VT	1	1	1
x)	Environmental and physiological factors	—	1	1
xi)	Advanced imaging systems	—	1	2
xii)	Quality assurances and standardization	—	—	2
xiii)	Organization and administration of NDT	—	—	2
xiv)	Qualification and certification of NDT personnel	—	—	1
	Total	**16**	**24**	**24**

Inspection Method : Visual Testing
Level I

Subject 1	**General Knowledge**	**4 h**

1.1 Non-destructive testing of materials, Definitions, reasons for using NDT, description and field of application of the most common methods, Comparison between methods.

1.2 Materials, discontinuities, defects, properties of material, properties of metal.

1.3 Defects originating from melting, pouring, cooling. Processing defects from welding, forging, rolling, hear treatment, machining, plating etc, service defects due to overload, fatigue, corrosion, brittle, fracture, and others.

Subject 2	**Fundamentals of Optics**	**2 h**

2.1 Electromagnetic spectrum-light-properties — reflection and refraction

2.2 Mirrors and lenses.

2.3 Lighting measurement.

2.4 Lighting techniques for inspection and recommended levels.

Subject 3	**Vision**	**1 h**

3.1 Visual perception.

3.2 Eye-structure — functions — disorders.

3.3 Vision examination methods.

Subject 4	**Material Characteristics and Attributes**	**1 h**

4.1 Size.

4.2 Shape.

4.3 Colour.

4.4 Texture.

4.5 Cleanliness.

4.6 Geometry.

Subject 5	**Aids to Visual Testing**	**3 h**

5.1 Magnifiers, mirrors, microscopes, borescopes, fiberscope, gages, templates, scales, micrometers, callipers, special tools, surface comparators and lasers.

5.2 Replication.

5.3 Temperature measurement.

5.4 Chemical aids.

Subject 6	**Applications**	**2 h**

6.1 Raw materials.

6.2 Welds.

6.3 Castings.

6.4 Fabricated components.

6.5 In-service materials.

6.6 Procedures for visual inspection — Selection of parameters, Inspection pattern and check points, Calibration and testing, Identification of indications.

Subject 7	**Codes, Standards and Personnel Certification**	**1 h**

7.1 Overview of codes and standards.

7.2 Acceptance standards.

7.3 Identification and classification of indications as per acceptance standards.

Subject 8	**Evaluation, Interpretation and Recording**	**1 h**

8.1 Variables affecting VT, Determination of dimension, recording and documentation.

Subject 9	**Safety in VT**	**1 h**

9.1 Electrical.

9.2 Mechanical.

9.3 Lighting hazard.

9.4 Chemicals.

9.5 Radioactive materials.

9.6 Explosive environments.

Visual Aid, Level I — Practicals

a) Familiarization with aids to visual testing;
b) Familiarization and handling mechanical aids, such as, venires callipers, micrometers and gauges for weld dimensional measurements;
c) Demonstration of borescopes and fiberscope; and
d) Appearance of various discontinuities encountered during fabrication and machining processes.

Inspection Method : Visual Testing
Level II

Subject 1	**General Knowledge**	**4 h**

1.1 Basic principles of NDT, Definitions, methodology of applications, Areas of application of common methods, Range and limitations of common methods.

1.2 Materials and defects, Structure of metals and alloys, Physical and mechanical properties of metallic materials, Discontinuities and defects in metallic materials.

1.3 Processing defects, Primary processes and related defects, Manufacturing processes and related defects.

1.4 Materials in service, Behaviour of materials in service, Service conditions leading to defects and failures : (a) Corrosion, (b) Fatigue, (c) Wear, (d) Overload, (e) Brittle fracture, Concepts of rupture development in metal.

1.5 Quality and standardization, Definition of quality, quality, control, standardization. Development of a quality system, Examination, testing and inspection, Standards, Codes, Specifications and procedures, Reports, records and protocols.

Subject 2 Fundamentals of Optics 2 h

2.1 Electromagnetic spectrum — light-properties-theories-reflection, refraction, interference, diffraction.

2.2 Mirrors and lenses — focal length, power.

2.3 Lighting measurement.

2.4 Lighting techniques for inspection and recommended levels.

Subject 3 Vision 2 h

3.1 Visual perception.

3.2 Eye-structure-functions-disorders.

3.3 Vision examination methods.

Subject 4 Material Characteristics and Attributes 1 h

4.1 Size.

4.2 Shape.

4.3 Colour.

4.4 Texture.

4.5 Type.

4.6 Cleanliness.

4.7 Geometry.

Subject 5 Aids to Visual Testing 4 h

5.1 Magnifiers, mirrors.

5.2 Microscopes — types, applications.

5.3 Borescopes.

5.4 Fiberscopes.

5.5 Gages, templates, scales, micrometers, calipers, special tools.

5.6 Replication.

5.7 Temperature measurement.

5.8 Chemical aids.

5.9 Surface comparators.

5.10 Lasers.

Subject 6 Applications 4 h

6.1 Raw materials.

6.2 Welds.

6.3 Castings.

6.4 Fabricated components.

6.5 In-service materials.

Subject 7	Codes, Standards, Specification Personnel Qualification and Certification	2 h

7.1 Codes, standards, specifications.

7.2 Acceptance criteria.

7.3 Sampling plans — check points — inspection procedure.

Subject 8	Evaluation, Interpretation and Recording	2 h

8.1 Variables affecting VT — Equipment including type and intensity of light, Material including the variations of surface finish, Discontinuity, Determination of dimensions, that is, depth, width, length, etc, Sampling/scanning, Process for reporting visual discontinuities, Personnel (human factors).

8.2 Recording and reporting.

8.3 Documentation — types and methodologies.

Subject 9	Safety in VT	1 h

9.1 Electrical.

9.2 Mechanical.

9.3 Electromagnetic radiations.

9.4 Chemicals.

9.5 Radioactive materials.

9.6 Explosive environments.

Subject 10	Environmental and Physiological Factors	1 h

10.1 Atmosphere.

10.2 Cleanliness.

10.3 Comfort.

10.4 Distance.

10.5 Elevation.

10.6 Fatigue.

10.7 Health.

10.8 Humidity.

10.9 Mental attitude.

10.10 Position.

10.11 Safety.

10.12 Temperature.

Subject 11 **Advanced Imaging Systems** **1 h**

11.1 Block diagram of imaging systems — imaging sensors.

11.2 CCD.

11.3 Video image scopes.

11.4 Video imaging — resolution.

11.5 Image processing — fundamentals and applications.

11.6 Machine vision.

Visual Testing, Level II — Practicals

a) Familiarization with aids to visual testing;

b) Familiarization and handling mechanical aids, such as, vernier callipers, micrometers and gauges for weld dimensional measurements;

c) Demonstration of microscopes, borescopes and fibrescopes;

d) Appearance of various discontinuities encountered during fabrication and machining processes,

e) Demonstration of remote viewing devices; and

f) Procedure writing.

Inspection Method : Visual Testing
Level III

Subject 1 **General Knowledge (covered in Basic)**

Subject 2 **Fundamentals of Optics** **2 h**

2.1 Electromagnetic spectrum theories — properties of visible and IR radiation — reflection, interference, diffraction, polarization, total internal reflection, coherent sources.

2.2 Mirrors and lenses — calculation of focal length, radius of curvature, power.

2.3 Physics of lighting measurement.

2.4 Lighting techniques for inspection and recommended levels.

Subject 3 **Vision** **2 h**

3.1 Physiology of sight.

3.2 Visual perception, acuity, angle and distance.

3.3 Eye-structure — functions — disorders.

3.4 Vision examination methods — Colour vision.

Subject 4 **Material Characteristics and Attributes** **1 h**

4.1 Size and shape.

4.2 Colour.

4.3 Texture.

4.4 Type.

4.5 Cleanliness.

4.6 Geometry.

Subject 5 Aids to Visual Testing 3 h

5.1 Magnifiers, mirrors and microscopes.

5.2 Borescopes (conventional and special purpose), fibrescopes.

5.3 Gages, templates, scales, micrometers, callipers, special tools.

5.4 Replication.

5.5 Temperature measurement — Contact and non-contact.

5.6 Chemical aids.

5.7 Surface comparators.

5.8 Lasers.

Subject 6 Applications 3 h

6.1 Raw and process materials.

6.2 Welds.

6.3 Castings.

6.4 Fabricated components — pumps — valves — bearings.

6.5 Ceramics.

6.6 Composites.

6.7 Glasses.

6.8 Plastics.

6.9 Electronics.

6.10 In-service inspection.

Subject 7 Codes, Standards, Specification, Personnel, Qualification and Certification 2 h

7.1 Codes, Standards, Specification, Personnel, Qualification and Certification.

Subject 8 Evaluation, Interpretation and Recording 2 h

8.1 Variables affecting VT — Equipment including type and intensity of light, Material including the variations of surface finish, Discontinuity, Determination of dimensions (that is, depth, width, length, etc), Process for reporting visual discontinuities, Personnel (human factors).

8.2 Recording and reporting — Documentation — Hard copy — Photography — Audio/ Video — Electronic and magnetic media.

Subject 9 **Safety in VT** **1 h**

9.1 Electrical.

9.2 Mechanical.

9.3 Lighting hazard.

9.4 Chemicals.

9.5 Radioactive materials.

9.6 Explosive environments.

9.7 Ultra-violet and infrared hazards.

Subject 10 **Environmental and Physiological Factors** **1 h**

10.1 Atmosphere.

10.2 Cleanliness.

10.3 Comfort.

10.4 Distance.

10.5 Elevation.

10.6 Fatigue.

10.7 Health.

10.8 Humidity.

10.9 Mental attitude.

10.10 Position.

10.11 Safety.

10.12 Temperature.

Subject 11 **Advanced Imaging Systems** **2 h**

11.1 Block diagram of imaging systems.

11.2 Imaging sensors — photoelectronic devices — CCD — diode arrays.

11.3 Video image scopes.

11.4 Video imaging — resolution.

11.5 Image processing — fundamentals and applications.

11.6 Machine vision.

Subject 12 **Quality Assurance and Standardization** **2 h**

12.1 Quality assurance; basic principles for the application of quality assurance — Organization of quality assurance — Quality manual, quality control; auditing of quality. Management and control of quality assurance documentation, quality control of testing, Reports on testing, documentation system.

12.2 Standardization — Definition of standardization, Principles of standard writing, Standards, Codes, Specifications and procedures, their uses — Reports and protocols.

Subject 13	**Organization and Administration of NDT Safety**	**2 h**

13.1 Organization and administration of NDT Safety (a) Implementation of industrial safety in facilities and their operation, (b) Hazards of using toxic and inflammable materials, (c) Materials, accessories and equipment for the protection of per and facilities.

13.2 Organization — Equipment for work under way, logistic provision, testing on production lines, Flow of materials, Work shifts, Maintenance of equipment and facilities.

13.3 Costs — Investment in equipment, Direct and indirect staff costs, Calculation and analysis of costs and profitability.

13.4 Equipment selection and facility design — Operation procedures and record keeping.

Subject 14	**Qualification and Certification of NDT Personnel**	**1 h**

14.1 Qualification and certification of personnel for NDT — National standards for the qualification and certification of personnel — Training of personnel for NDT — Organization of courses and training in NDT methods — Code of ethics.

Inspection Method : Neutron Radiographic Testing (Summary)

Sl No.	Subject	Hours of Training		
		Level I	Level II	Level III
(1)	(2)	(3)	(4)	(5)
i)	General knowledge	4	4	—
ii)	Physical principles	2	3	3
iii)	Neutron sources	3	4	4
iv)	Neutron detection	5	8	7
v)	Basic imaging considerations	5	8	6
vi)	Test result interpretation and recording	2	3	5
vii)	Codes and standards	1	2	2
viii)	Personnel safety and radiation protection	6	6	6
ix)	Advances in neutron radiography	—	2	2
x)	Quality assurances and standardization	—	—	2
xi)	Organization and administration of NDT	—	—	2
xii)	Qualification and certification of NDT personnel	—	—	1
	Total	**28**	**40**	**40**

Inspection Method : Neutron Radiographic Testing Level I

Subject 1	**General Knowledge**	**4 h**

1.1 Non-destructive testing of materials, Definitions reasons for using NDT, description and field of application of the most common methods, comparison between methods.

1.2 Materials, discontinuities, defects, properties of material, properties of metal.

1.3 Defects originating from melting, pouring, cooling. Processing defects from welding, forging, rolling, hear treatment, machining, plating, etc, service defects due to overload, fatigue, corrosion, brittle, fracture, and others.

Subject 2 — Physical Principles — 2 h

2.1 Basic radiations physics, general principle of neutron radiography and comparison with X-radiography, advantages and limitations.

2.3 Interaction of neutrons with matter — absorption, scattering, thermal neutrons, resonance neutrons, fast neutrons.

Subject 3 — Neutron Sources — 2 h

3.1 Reactors — Principle of fission chain reactions, neutron thermalization (slowing down), Thermal neutron flux.

3.2 Accelerators — Types of accelerators and neutron – producing reactions.

3.3 Isotopic sources.

3.4 Principles of moderation and collimation.

Subject 4 — Neutron Detection — 5 h

4.1 Converter screens — Principles of operation relationship, Direct imaging screens, + transfer-imaging screens.

4.2 Film — principles, properties, and uses with neutron converter screens, Radiation response, Vacuum / contact considerations, Radiographic speed, Radiographic contrast.

4.3 Track-etch-radiation response, Vacuum /contact considerations, Radiographic speed, Radiographic contrast.

Subject 5 — Basic Imaging Considerations — 5 h

5.1 Definition of sensitivity (including penetrameters), Contrast and definition, Neutron energy and neutron screen relationship, Effect of scattering in object.

5.2 Geometric principles.

5.3 Generation and control of scatter.

5.4 Choice of neutron source, Choice of film, Use of exposure curves.

5.5 Cause of correction of unsatisfactory radiographs — High film density, low film density, high contrast, low contrast, poor definition, excessive film fog, light leaks, artefacts.

5.6 Arithmetic of exposure.

Subject 6 — Test Result Interpretation and Recording — 2 h

6.1 Relationship between X-ray and neutron radiographs and familiarisation with image.

6.2 Effects on measurement and interpretation of test.

6.3 Administrative control of test quality by interpreter.

6.4 Recording and documentation.

Subject 7 — Codes and Standards — 1 h

7.1 Codes, Standards and Specifications

Subject 8 — Personnel Safety and Radiation Protection — 6 h

8.1 Hazards of excessive exposure — Beta, gamma and neutrons, Relative biological effectiveness.

8.2 Methods of controlling radiation dose — Time, distance, shielding.

8.3 Specific equipment requirements — Neutron monitoring dosimeters, gamma-ray monitoring dosimeters, radiation survey equipment (beta, gamma, neutron), recording/record-keeping.

8.4 Radiation work procedures and regulations.

Neutron Radiography Testing, Level I — Practicals and Demonstrations

a) Demonstration of operation of neutron source,
b) Demonstration of use of converter screens and films,
c) Viewing of radiographs — Demonstration,
d) Practical — Taking radiograph of a given sample,
e) Demonstration — Relating defects and its image on radiograph, and
f) Radiation monitoring instruments.

Inspection Method : Neutron Radiographic Testing
Level II

Subject 1 **General Knowledge** **4 h**

1.1 Basic principles of NDT, Definitions, methodology of applications, Areas of application of common methods, Range and limitations of common methods.

1.2 Materials and defects, Structure of metals and alloys, Physical and mechanical properties of metallic materials, Discontinuities and defects in metallic materials.

1.3 Processing defects, primary processes and related defects, Manufacturing processes and related defects.

1.4 Materials in service, Behaviour of materials in service, Service conditions leading to defects and failures : (a) Corrosion, (b) Fatigue, (c) Wear, (d) Overload, (e) Brittle fracture, Concepts of rupture development in metals.

1.5 Quality and standardization, Definition of quality, quality control, standardization. Development of a quality system, Examination, testing and inspection, Standards, Codes, Specifications and procedures, Reports, records and protocols.

Subject 2 **Physical Principles** **3 h**

2.1 Nature of penetrating radiation — Particles, Wave properties, Electromagnetic waves, Fundamentals of radiation physics.

2.2 Interaction between penetrating radiation and matter (neutron and gamma-ray, absorption, scatter, other interactions.

2.3 Glossary of terms and units of measure.

Subject 3 **Neutron Sources** **4 h**

3.1 Reactors — Principle of fission chain reactions, fast-neutron flux-energy and spatial distribution.

3.2 Accelerators — Types, Neutron-producing reactions, Available yields and energy spectra.

3.3 Isotopic sources — Radioisotope + Be, radioisotope + D, spontaneous fission — 252 Cf.

3.4 Neutron thermalisation.

3.5 Thermal-neutron flux-energy and spatial distribution.

3.6 Collimation and shielding.

Subject 4	Neutron Detection	8 h

4.1 Converter screens — Types, direct exposure, transfer exposure.

4.2 Track-etch process.

4.3 Film-Principles, properties, use with neutron converter screens.

4.4 Non-imaging devices — Solid state, gaseous, neutron detectors (boron based gas counters, fission counters, helium -3 detectors, lithium based scintillator).

Subject 5	Basic Imaging Considerations	8 h

5.1 Basic neutron-imaging considerations — Definition of sensitivity (including image quality indicators), contrast and definition, neutron energy and neutron screen relationship, effect of scattering in object, exposure curves, exposure *versus* foil thickness.

5.2 Generation and control of scatter.

5.3 Film processing — Darkroom procedures, darkroom equipment and chemicals. Manual and automatic processing.

5.4 Viewing of radiographs — Illuminator requirements, Background lighting, Judging quality of neutron radiographs.

5.5 Causes and correction of unsatisfactory radiographs — High film density, Insufficient film density, High contrast, Low contrast, Poor definition, Excessive neutron scatter, Fog, Light leaks, Artefacts.

Subject 6	Test Result Interpretation	3 h

6.1 Basic factors — General aspects (relationship between X-ray and neutron radiographs), Effects on measurement and interpretation of test, Administrative control of test quality by interpreter, Familiarization with image.

6.2 Material considerations.

6.2 Discontinuities — Their causes, effects and radiographic appearance.

Subject 7	Codes and Standards	2 h

7.1 Codes, Standards, Specifications applicable to thermal neutron radiography.

7.2 Other applicable codes etc.

7.3 Procedures.

Subject 8	Personnel Safety and Radiation Protection	6 h

8.1 Hazards of excessive exposure — Beta, gamma-ray, neutron hazards, relative biological effectiveness (RBE), neutron activation of components.

8.2 Methods of controlling accumulated radiation dose — Time, distance and shielding.

8.3 Specific equipment requirements — Neutron and gamma-ray monitoring equipment, survey meters, dosimeters, recording, exposure shields and/or rooms, alarms.

8.4 Operation and emergency procedures.

8.5 Regulations.

Subject 9	Advances in Neutron Radiography	2 h

9.1 Real time neutron radioscopy.

9.2 Application of image processing in neutron radiography.

9.3 Digital neutron radiography and neutron tomography.

Radiography Testing, Level II — Practicals

a) Familiarization with neutron source,
b) Darkroom practices and preparation of exposure parameters,
c) Evaluation of reference radiographs,
d) Relating discontinuities with the radiographic images,
e) Selection of radiography technique,
f) Preparation of test procedures and model reports,
g) Familiarization with radiation safety equipment, monitors, dosimeters, warning symbols, etc, and
h) Area monitoring and personal monitoring.

Inspection Method : Neutron Radiographic Testing
Level III

Subject 1 **General Knowledge (covered in Basics)**

Subject 2 **Physical Principles** **3 h**

2.1 Nature of penetrating radiation — Particles, Wave properties, electromagnetic waves, fundamentals of radiation physics.

2.2 Interaction between penetrating radiation and matter (neutron and gamma-ray), absorption, scatter, other interactions.

2.3 Glossary of terms and units of measure.

Subject 3 **Neutron Sources** **4 h**

3.1 Reactors — Principle of fission chain reactions, fast-neutron flux — energy and spatial distribution.

3.2 Accelerators — Types, neutron-producing reactions, available yields and energy spectra.

3.3 Isotopic sources — Radioisotope +Be, radioisotope +D, spontaneous fission – 252 Cf.

3.4 Neutron thermalization.

3.5 Thermal-neutron flux-energy and spatial distribution.

3.6 Collimators — Types, design and shielding.

Subject 4 **Neutron Detection** **7 h**

4.1 Converter screens — Types, direct exposure, transfer exposure.

4.2 Track-etch process.

4.3 Film — Types, characteristics, properties, use with neutron converter screens.

4.4 Fluoroscopy — Fluorescent screen, image intensifier systems — special instrumentation associated with above techniques.

4.5 Non-imaging devices — Solid state, gaseous, neutron detectors (boron based gas counters, fission counters, helium –3 detectors, lithium based scintillator).

Subject 5	Basic Imaging Considerations	6 h

5.1 Basic neutron-imaging considerations — Definition of sensitivity (including image quality indicators), contrast and definition, neutron energy and neutron screen relationship, effect of scattering in object, exposure curves, exposure *versus* foil thickness.

5.2 Generation and control of scatter.

5.3 Film processing — Principles, processes, darkroom procedures, darkroom equipment and chemicals, film processing do's and don'ts.

5.4 Viewing of radiographs — Illuminator requirements, Background lighting, Judging quality of neutron radiographs.

5.5 Causes and correction of unsatisfactory radiographs — High film density, Insufficient film density, High contrast, Low contrast, Poor definition, Excessive neutron scatter, Fog, Light leaks, Artefacts.

Subject 6	Test Result Interpretation	5 h

6.1 Basic factors — General aspects (relationship between X-ray and neutron radiographs), Effects on measurement and interpretation of test, Administrative control of test quality by interpreter, Familiarization with image.

6.2 Material considerations — Metallurgy or other material consideration as it affects use of item and test results, materials-processing effects on use of item and test results.

6.3 Discontinuities — Their causes and effects, radiographic appearance.

Subject 7	Codes and Standards	2 h

7.1 Codes, standards, specifications, and procedures — thermal neutron radiography.

7.2 Other applicable codes etc.

7.3 Procedures.

Subject 8	Personnel Safety and Radiation Protection	8 h

8.1 Hazards of excessive exposure — Beta, gamma and neutrons, specific neutron hazards, relative biological effectiveness (RBE), neutron activation of components.

8.2 Methods of controlling accumulated radiation dose — Time, distance and shielding.

8.3 Specific equipment requirements — Neutron and gamma-ray monitoring equipment, survey meters, dosimeters, recording, exposure shields and/or rooms, alarms.

8.4 Operation and emergency procedures.

8.5 Regulations.

Subject 9	Advances in Neutron Radiography	2 h

9.1 Real time neutron radioscopy.

9.2 Application of image processing in neutron radiography.

9.3 Digital neutron radiography and neutron tomography.

Subject 10	Quality Assurance and Standardization	2 h

10.1 Quality assurance; basic principles for the application of quality assurance — Organization of quality assurance — Quality manual, quality control; auditing of quality. Management and control of quality assurance documentation, quality control of testing, Reports on testing, documentation system.

10.2 Standardization — Definition of standardization — Principles of standard writing, Standards, codes; specifications and procedures, their uses — Reports and protocols.

Subject 11 **Organizations and Administration of NDT Safety** **2 h**

11.1 Organization and administration of NDT Safety: (a) Implementation of industrials safety in facilities and their operation, (b) Hazards of using toxic and inflammable materials, (c) Materials, accessories and equipment for the protection of persons and facilities.

11.2 Organization — Equipment for work under way, logistic provision, testing on production lines, Flow of materials, Work shifts, Maintenance of equipment and facilities.

11.3 Costs — Investment in equipment, Direct and indirect staff costs, Calculation and analysis of costs and profitability.

11.4 Equipment selection and facility design—Operation procedures and record keeping.

Subject 12 **Qualification and Certification of NDT Personnel** **1 h**

12.1 Qualification and certification of personnel for NDT — National standards for the qualification and certification of personnel — Training of personnel for NDT — Organization of courses and training in NDT methods — Code of ethics.

Inspection Method : Infrared Testing
(Summary)

Sl No.	Subject	Hours of Training		
		Level I	Level II	Level III
(1)	(2)	(3)	(4)	(5)
i)	General knowledge	4	4	—
ii)	Physical principles of IR methods	3	4	3
iii)	Equipment and instrumentation	4	5	2
iv)	Testing techniques	8	6	2
v)	Calibration	4	4	2
vi)	Applications	6	6	2
vii)	Specific applications	8	6	2
viii)	Recording and evaluation of test results	2	2	2
ix)	Codes, standards and procedures	1	2	2
x)	Special techniques	—	1	1
xi)	Advances in IR	—	—	1
xii)	Quality assurance and standardization	1	2	2
xiii)	Organization and administration of NDT safety	—	—	2
ix)	Qualification and certification of NDT personnel	—	—	1
	Total	**40**	**40**	**24**

Inspection Method : Infrared Testing
Level I

Subject 1 **General Knowledge** **4 h**

1.1 Non-destructive testing of materials, Definitions reasons for using NDT, Description and field of application of the most common methods, Comparison between methods.

1.2 Materials, discontinuities, defects, properties of material, properties of metal.

1.3 Defects originating from melting, pouring, cooling. Processing defects from welding, forging, rolling, hear treatment, machining, plating, etc, service defects due to overload, fatigue, corrosion, brittle, fracture, and others.

Subject 2	Physical Principles of IR Methods	3 h

2.1 Nature of heat, its measurement; definition of various terms, temperature, its measurement and how it is expressed.

2.2 Heat transfer — Various types of heat flow — conduction, convection, and radiation — heat flow in solids — study state.

2.3 Thermal conductivity of materials — heat flows through metals, non-metals; definition of transient heat flow, its advantage in NDT of materials.

2.4 Thermal diffusivity — its relation to heat flow — difference between metals and non-metals; change in surface temperature in transient flow in presence of defects.

2.5 Infrared radiation, its electromagnetic nature — Quantum theory.

2.6 Black body radiation, Stefan Boltzmann equation; distribution of radiation in black body — Planck's distribution law – Emissivity.

Subject 3	Equipment and Instrumentation	4 h

3.1 Radiometric methods — Measurement of temperature; Principles, Different types of radiometers.

3.2 Different detectors of temperatures — Pyrometers, scanning radiometers.

3.3 Developments in detectors — Real-time Radiometers, array detectors, scanning video meters — Imaging of temperature concepts.

3.4 Advantages and disadvantages of various detectors — Readout devices — A scan and C scan recorders — Instrumentation of a typical optical scanner.

3.5 Other types of thermo-sensitive materials like paints, coatings — liquid crystals and their application as temperature indicators.

Subject 4	Testing Techniques	8 h

4.1 Various techniques of IR testing — Active and passive testing techniques — Effects of heat flow in testing methods.

4.2 Measurement of variables like temperatures, emissivity — selection of proper techniques.

4.3 Heating techniques and heat flow — excess / deficiency of heat — Heat soak, scan heating — Fixed / large area heating.

Subject 5	Calibration	4 h

5.1 Calibration of equipment — quantification of emissivity — estimation of back — ground radiation.

5.2 Measurement of temperature — calibrating for mapping of surface temperatures — calibration methods for various temperature sources.

5.3 Measurement of heat flux flow — calibration for measuring heat flux — calibration in presence of high temperature environment.

Subject 6	Applications	6 h

6.1 Application in the evaluation of composite materials — detection of disbands, resin starvation, fibre disorientation — Application for the evaluation of structural materials used in aerospace and other related industries.

6.2 Application for evaluation of structure and condition of building envelopes — for the evaluation of masonry deficiencies; defects in concrete — detection of moisture in building structures and other building (civil) applications.

6.3 Application in electric power distribution and transmission systems — detection of defects as heat due to energy loss.

6.4 Application in condition monitoring of chemical/petro-chemical industries — for evaluation of furnace tubes, fluid transfer lines, wear estimation of refractories — Inspection of rotary kiln lining, evaluation of heat resistant linings, etc.

6.5 Application for bonded materials and structure — evaluation of bond integrity in bonded lap joints — use of high emissivity materials to enhance inspection efficiency and other applications.

6.6 Other applications of IR in medical, consumer industry art, conservation, automotive industry, vacuum systems, forest fire surveillance geothermal source survey rescue missions, etc.

Subject 7 Specific Applications 8 h

7.1 Application of IR in petro-chemical and chemical industries with specific case studies — also in oil refineries, fertilizers metal extracting industries.

7.2 Application in nuclear industries — as an in-service and pre-service inspection tool — in maintenance of plants.

7.3 In space and aerospace industries — for evaluation of integrity of multi-layered components for bond inspection — application for the inspection of specific composite materials like honeycomb structures used in aircraft, space craft.

7.4 IR applications in electrical distribution and transmission lines as on-line inspection tool used in Electricity Boards — other miscellaneous applications.

7.5 Application in the evaluation of printed circuit boards. Application for the evaluation of other electronic components.

Subject 8 Recording and Evaluation of Test Results 2 h

8.1 Obtaining good IR image on the recording medium, such as, videotape, video cameras, digital and video printers.

8.2 Evaluation of the recorded data — comparisons with environmental data — evaluation with respect to black body reference — measurement of emittance, surface temperature, and other properties.

Subject 9 Codes, Standards and Procedures 1 h

9.1 General knowledge on Codes and Standards — Introduction to various International Codes and Standards.

9.2 General information on various specifications and procedures performance of test according to specific requirement — performance as per written instructions of the test method.

Infrared Testing : Level I — Practical

a) Equipment familiarization — demonstration of various functions — types of equipment (cryogenic cooled and other type detector based) — their demonstration and operation,

b) Calibration of equipment using various reference sources including standard sources — demonstration and familiarization of thermographic methods (active and passive) — familiarization of different heating techniques and imaging methods,

c) Demonstration of application on specific samples showing bond and disbond conditions — familiarization of detection of hidden defects in non-metals like resin starvation in composite materials used in various industries, and

d) Demonstration of applications on other specimens including metallic welded plates.

Inspection Method : Infrared Testing

Level II

Subject 1 — General Knowledge — 4 h

1.1 Basic principles of NDT, Definitions, methodology of applications, Areas of application of common methods, Range and limitations of common methods.

1.2 Materials and defects, Structure of metals and alloys, Physical and mechanical properties of metallic materials, Discontinuities and defects in metallic materials.

1.3 Processing defects, primary processes and related defects, Manufacturing processes and related defects.

1.4 Materials in service, Behaviour of materials in service, Service conditions leading to defects and failures : (a) Corrosion, (b) Fatigue, (c) Wear, (d) Overload, (e) Brittle fracture, Concepts of rupture development in metals.

1.5 Quality and standardization, Definition of quality, quality control, standardization. Development of a quality system, Examination, testing and inspection, Standards, Codes, Specifications and procedures, Reports, records and protocols.

Subject 2 — Physical Principles of IR Method — 4 h

2.1 Nature of heat, Definitions of various terms — temperature; fundamentals of its measurement and other expressions.

2.2 Heat transfer — Different modes of heat transfer and types of heat flow — Description of conduction, convection and radiation — heat flow in solids — steady state.

2.3 Thermal conductivity and heat flow through materials — metals, non-metals and composite materials; transient heat flow, its use in non-destructive testing of materials.

2.4 Thermal diffusivity, its relation to heat flow — Difference in metal and non-metals — Effect of heat flow in presence of defects and change in surface temperature.

2.5 Infrared radiation, its electromagnetic properties including quantum theory — radiometric quantities — radioactive properties of materials including non-metals and composits.

2.6 Black body radiation — Stefan Boltzman's law and its equation — Distribution of radiation in black body — Planck's distribution law – Definition of emissivities.

Subject 3 — Equipment and Instrumentation — 5 h

3.1 Radiometric methods — Principles of temperature measurements — Different types of radiometry — Historical developments of heat measuring devices.

3.2 Detectors in thermography — Different characteristics of detectors — Minimum resolvable temperature difference and its measurement in IR thermography.

3.3 Cooling of detectors — Signal degradation — Noise, its suppression device — Sensitivity of defects — Importance and selection of atmospheric band for IR methods.

3.4 Real-time detectors — array detectors — imaging detectors IR focal plane arrays — SPRITE detector and its various concepts.

3.5 Thermal imaging concepts — image processing in thermography; optimization of image using image processing techniques.

3.6 Relative merits/demerits of various detectors — read-out devices — A and C scan recorders and their instrumentation.

3.7 Other types of thermo sensitive indicators like paints, coatings, liquid crystals and their application in NDT.

Subject 4 **Testing Techniques** **6 h**

4.1 Various testing techniques in IR — active and passive methods — effects of heat flow on testing.

4.2 Measurement of thermal properties of materials — diffusivity, emissivity — non-selection of proper techniques.

4.3 Heat flow variation — dependence on heating techniques — point heating, area heating and uniform heating etc.

4.4 Characterization of defects — different approaches of characterization using pulse duration, finite optical penetration of radiation heat loss, etc — dependence of characterization on thermal properties of material.

Subject 5 **Calibration of Testing Equipment** **4 h**

5.1 Calibration of testing equipments with reference to emissivity — Estimation of background radiation — setting-up of optimum levels for thermal imaging.

5.2 Calibration for temperature measurements — mapping surface temperature — use of reference black bodies — calibration methods for different sources.

5.3 Calibration for measurement of other thermal properties of materials like emissivity, diffusivity, total heat flux — calibration in presence of high temperature environment.

5.4 Calibration using standard specimens having defect — Calibration with defects in composites, multi-layered components, etc.

Subject 6 **Applications** **6 h**

6.1 Application in the evaluation of composite materials — detection of disbonds, resin starvation, fibre disorientation — for the evaluation of structural materials used in aerospace and other industries.

6.2 Application for evaluation of structure and condition of building envelopers — for evaluation of masonry deficiencies, defects in concrete, detection of moisture in building structure and other building applications.

6.3 Application in electric power distribution and transmission system — detection of defects as heat due to energy loss.

6.4 Application in condition monitoring of chemical/petrochemical industries — for evaluation of furnace tubes, fluid transfer lines, wear estimation of refractories — Inspection of rotary kiln lining, evaluation of heat-resistant linings, etc.

6.5 Application for bonded materials and structures — evaluation of bond integrity in bonded lap joints — use of high emissivity materials to enhance inspection efficiently and other applications.

6.6 Other applications of IR — medical, consumer industry art, conservation, automotive industry, vacuum systems, forest fire surveillance, and geo-thermal source survey rescue mission etc.

Subject 7 **Specific Applications** **6 h**

7.1 Application of IR in petrochemical and chemical Industries — oil refineries, fertilizers metal extracting industries.

7.2 Application in nuclear industries — as in-service and pre-service inspection — Application for specific composite materials like honey comb structures used in aircraft and spacecrafts.

7.3 In Space and Aerospace industries — evaluation of multi-layered components for bond line inspection — Application for specific composite materials like honeycomb structures used in aircraft and spacecrafts.

7.4 IR applications in electrical distribution and transmission lines as on-line inspection tool used in Electricity Boards — other miscellaneous applications.

7.5 Applications in the evaluation of printed circuit boards. Application for the evaluation of other electronic components.

Subject 8 **Recording Methods** **2 h**

8.1 Obtaining of good IR image on the recording medium such as videotape, video cameras, digital and video printers.

8.2 Evaluation of the recorded data — comparisons with environmental data — evaluation with respect to black body reference — measurement of emittance surface temperature.

8.3 Thermal image acquisition — Introduction to image processing to optimize image quality — Explanation of various image processing functions.

Subject 9 **Codes, Standards, Procedures** **2 h**

9.1 General knowledge — Introduction to various International Codes and Standards.

9.2 General information on various specifications and procedures — performance of test according to specific requirement. Performance as per written instructions of the test method.

Subject 10 **Special Techniques**

10.1 Dedicated image processing of IR images — Software image processing — Review on various software available.

10.2 Hardware requirements of IR image processing — Introduction to quantitative processing of thermographics images — Interactive software for image processing.

Infrared Testing Level II — Practicals

a) Equipment familiarization — demonstration of various functions — types of equipment (cryogenic cooled and other type detector based) — their demonstration and operation,

b) Calibration of equipment using various reference sources including standard sources — demonstration and familiarization of thermographic methods (active and passive) familiarization of different heating techniques and imaging methods,

c) Demonstration of application on specific samples showing bond and disbond conditions — familiarization of detection of hidden defects in non-metals like resin starvation in composite materials used in various industries,

d) Demonstration of applications on other specimens including metallic welded plates, and

e) Demonstration of IR applications for evaluation of electronic PCBs and other electronic components of utility.

Inspection Method : Infrared Testing
Level III

Subject 1 **General Knowledge (covered in Basic)**

Subject 2 **Physical Principles of IR Method** **3 h**

2.1 Nature of heat, Definitions of various terms — temperature; fundamentals of its measurement and other expressions.

2.2 Heat transfer — Different modes of heat transfer and types of heat flow — Description of conduction, convection and radiation — heat flown in solids-steady state.

2.3 Thermal conductivity and heat flow through materials — metals, non-metals and composite materials; transient heat flow, its use in non-destructive testing of materials.

2.4 Thermal diffusivity, its relation to heat flow — Difference in metal and non-metals and composite materials; transient heat flow in presence of defects and change in surface temperature.

2.5 Infrared radiation, its electromagnetic properties including quantum theory — radiometric quantities — radioactive properties of material including non-metals and composits.

2.6 Black body radiation — Stefan Boltzman's law and its equation — distribution of radiation in black body — Planck's distribution law — definition of emissivities.

Subject 3 — Equipment and Instrumentation — 2 h

3.1 Radiometric methods — Principles of temperature measurements — Different types of radiometry — Historical developments of heat measuring devices — Detectors and their characteristics — minimum resolvable temperature difference and its measurement.

3.2 Cooling of detectors — signal degradation — noise, its suppression devices — sensitivity of defects — importance and selection of atmospheric band for IR methods — Real-time detectors — array detectors — imaging detectors — focal plane arrays — SPRITE detector.

3.3 Thermal imaging concepts — image processing in thermography; optimization of image using image-processing techniques. Relative merits/demerits of various detectors read-out devices — A and C scan recorders and their instrumentation.

3.4 Other types of thermo sensitive indicators like paints, coatings, liquid crystals and their application in NDT.

Subject 4 — Testing Techniques — 2 h

4.1 Various testing techniques — active and passive methods — effects of heat flow on testing.

4.2 Measurement of thermal properties of materials — diffusivity, emissivity, non-contact temperature measurement; selection of proper techniques. Heat flow variation — dependence on heating techniques — point heating, area heating and uniform heating, etc.

4.3 Characterization of defects — different approaches of characterization using pulse duration, finite optical penetration of radiation heat loss, etc — dependence of characterization on thermal properties of material.

Subject 5 — Calibration — 2 h

5.1 Calibration of testing equipment with reference to emissivity — estimation of back ground radiation — setting-up of optimum levels for thermal imaging.

5.2 Calibration of temperature measurements — mapping surface of temperature — use of reference black bodies — calibration methods for different sources.

5.3 Calibration for measurement of other thermal properties of materials like emissivity, diffusivity, total heat flux — calibration in presence of high temperature environment.

5.4 Calibration using standard specimens having defect — calibration with defects in composites, multi-layered components, etc.

Subject 6 — Applications — 2 h

6.1 Application in the evaluation of composite materials — detection of disbands, resin starvation, fibre disorientation — for the evaluation of structural materials used in aerospace and other industries.

6.2 Application for evaluation of structure and condition of building envelopes — for evaluation of masonry deficiencies, defects in concrete, detection of moisture in building structure and other building applications.

6.3 Application in electric power distribution and transmission systems — detection of defects as heat due to energy loss.

6.4 Application in condition monitoring of chemical/petro-chemical Industries — for evaluation of furnace tubes, fluid transfer line, wear estimation of refractories — inspection of rotary kiln lining, evaluation of heat — resistant linings, etc.

6.5 Application for bonded materials and structures — evaluation of bond integrity in bounded lap joints — use of high emissivity materials to enhance inspection efficiency and other applications.

6.6 Other applications of IR — medical, consumer industry art, conservation, automotive industry, vacuum systems, forest fire surveillance, and geothermal source survey rescue mission etc.

Subject 7 **Specific Applications** **2 h**

7.1 Application of IR in petro-chemical and chemical industries — oil refineries, fertilizers metal extracting Industries.

7.2 Application in nuclear industries — as in-service and pre-service inspection tool in maintenance of plants.

7.3 In space and aerospace industries — evaluation of multi-layered components for bond line inspection — application for specific composite materials like honey comb structures used in aircraft and space crafts.

7.4 IR applications in electrical distribution and transmission lines as on-line inspection tool used in Electricity Boards — other miscellaneous applications.

7.5 Applications in the evaluation of printed circuit boards. Application for the evaluation of other electronic components.

Subject 8 **Recording and Evaluation of Test Results** **2 h**

8.1 Obtaining of good IR image on the recording medium, such as, videotape, video cameras, digital and video printers.

8.2 Evaluation of the recorded data — comparisons with environmental data — evaluation with respect to black body reference — measurement of emittance, surface temperature.

8.3 Thermal image acquisition — introduction to image processing to optimize image quality — explanation of various image processing functions.

Subject 9 **Codes, Standards, Procedures** **2 h**

9.1 General knowledge — Introduction to various International Codes and Standards.

9.2 General information on various specifications and procedures — performance of test according to specific requirement — performance as per written instructions of the test method.

9.3 Comparison of various International Codes in regard to application to specific application — in relative merits and demerits.

Subject 10 **Special Techniques** **1 h**

10.1 Dedicated image processing of IR images — software of image processing — Review on various software available.

10.2 Hardware requirements of IR image processing — Introduction to quantitative processing of thermographic images — interactive software for image processing.

Subject 11 **Advances in IR** **1 h**

11.1 Thermographic stress analysis — Thermoelasticity theory and equipment; methods and materials — High temperature stress analysis and its applications.

11.2 Quantitative evaluation of damage by thermography — Vibrothermography — Comparison of vibrothermography XRT and UTC — scan methods — Applications of vibrothermography.

Subject 12 **Quality Assurance and Standardization** **2 h**

12.1 Quality assurance; basic principles for the application of quality assurance — Organization of quality assurance — Quality manual, quality control; auditing of quality. Management and control of quality assurance documentation, quality control of testing, Reports on testing, documentation system.

12.2 Standardization — Definition of standardization, Principles of standard writing, Standards, Codes; Specifications and procedures, their uses — Reports and protocols.

Subject 13 **Organization and Administration of NDT Safety** **2 h**

13.1 Organization and administration of NDT safety (a) Implementation of industrials safety in facilities and their operation, (b) Hazards of using toxic and inflammable materials, (c) Materials, accessories and equipment for the protection of per and facilities.

13.2 Organization — Equipment for work under way, logistic provision, testing on production lines, Flow of materials, Work shifts, Maintenance of equipment and facilities.

13.3 Costs — Investment in equipment, Direct and indirect staff costs, Calculation and analysis of costs and profitability.

13.4 Equipment selection and facility design — Operation procedures and record keeping.

Subject 14 **Qualification and Certification of NDT Personnel** **1 h**

14.1 Qualification and certification of personnel for NDT — National standards for the qualification and certification of personnel — Training of personnel for NDT — Organization of courses and training in NDT methods — Code of ethics.

Inspection Method : Leak Testing
(Summary)

Sl No.	Subject	Hours of Training		
		Level I	Level II	Level III
(1)	(2)	(3)	(4)	(5)
i)	General knowledge	4	4	—
ii)	Leak testing fundamentals	8	—	—
iii)	Safety in leak testing course	2	—	—
iv)	Physical principles in leak testing	—	2	2
v)	Principles of gas flow	—	3	4
vi)	Pressure technology	—	3	—
vii)	Vacuum technology	—	3	—
viii)	Leak test selection course and methods	12	12	—
ix)	Codes and Standards	—	2	2
x)	Interpretation/Evaluation and procedures	—	3	4
xi)	Equipment/Material	—	2	8
xii)	Testing practices, techniques and practicals	14	12	8
xiii)	Techniques/Calibration	—	—	6
xiv)	Safety and health	—	—	2
xv)	Quality assurance and standardization	—	—	2
xvi)	Organization and administration of NDT safety	—	—	1
xvii)	Qualification and certification of NDT personnel	—	—	1
	Total	**40**	**46**	**40**

Inspection Method : Leak Testing
Level I

Subject 1	**General Knowledge**	**4 h**

1.1 Non-destructive testing of materials, Definitions reasons for using NDT, description and field of application of the most common methods, Comparison between methods.

1.2 Materials, discontinuities, defects, properties of material, properties of metal.

1.3 Defects originating from melting, pouring, cooling. Processing defects from welding, forging, rolling, hear treatment, machining, plating, and etc. service defects due to overload, fatigue, corrosion, brittle, fracture, and others.

Subject 2	**Leak Testing Fundamentals**	**8 h**

2.1 Need for leak testing, Terminology — Leakage terms, Leakage tightness, Quantitative/semi-quantitative, Sensitivity/calibration terms.

2.2 Leak testing units — Mathematics in leak testing, Exponential notation, Basic and fundamental units, System International Units (SI).

2.3 Physical units in leak testing — Volume and pressure, Time and temperature, Absolute values, Standard or atmospheric conditions, Leakage measurements.

2.4 Leak testing standards — Capillary or permeation, National Institute of Standards and Technology (NIST) Standards, System *versus* Instrument calibration, Inaccuracy of calibration.

2.5 Flow characteristics — Gas flow, Liquid flow, Correlation of leakage rates, anomalous leaks, Leak clogging.

2.6 Vacuum fundamentals — Introduction to vacuum, Terminology, Principles, Units of pressure, Characteristics of gases, Kinetic theory, Mean free path, Gas laws, Quantity throughput and conductance of gas.

2.7 Quantity — Comparison with an electric circuit, Comparison with water flow.

2.8 Conductance analogy with electrical resistance, Resistance connected in series, Resistance connected in parallel.

2.9 Vacuum system operation — Effects of evacuating a vessel, Pump down time.

2.10 Vacuum system characteristics — General, Operating limits, Rate of pressure rise-measurement, vacuum pumps — Mechanical pumps (positive displacement, Oil-sealed rotary pumps — (a) Construction, (b) Operation, (c) Pump fluids, (d) Difficulties with rotary pumps, (e) Care of rotary pumps.

Mechanical Booster pumps — Vapour (diffusion) pumps : (a) Construction, (b) Operation, (c) Pump fluids, (d) Difficulties with diffusion pumps, (e) Diagnosis of diffusion pump trouble.

Sublimation pumps (getter pumps), Ion pumps, Turbo molecular pumps, Absorption pumps, Cryo pumps

Subject 3	**Safety in Leak Testing Course**	**2 h**

3.1 Safety considerations — Personnel and public, Product serviceability, Test validity, Safe work practices.

3.2 Safety precautions — Explosives/implosives hazards, Flammability, Ignitability, Combustibility hazards, Toxicity and asphyxiation hazards, leaning and electrical hazards.

3.3 Pressure precautions — Pressure test *versus* Proof test, Preliminary leak testing, Pressurization check, Design limitation, Equipment and set up.

3.4 Safety devices — Pressure control valves and regulators, Pressure relief valves and vents, flow rate of regulator and relief valves.

3.5 Hazardous and tracer gas safety — Combustible gas detection and safety, Toxic gas detection and safety, Oxygen — deficiency detectors, Radioisotope detection.

3.6 Types of monitoring equipment — Area monitors, Personnel monitors, Leak — locating devices.

3.7 Safety Regulations — State and federal regulations, Safety Codes/Standards, Hazardous gas standards, Nuclear regulatory commission (NRC) radiation requirements.

Leak Testing — Specific Methods Course

The following leak testing methods may be incorporated as applicable. Each of these methods can be further divided into major techniques as shown in the following examples.

1. Bubble testing — (a) Immersion, (b) Film solution.
2. Ultrasonic testing — (a) Sonic/mechanical flow, (b) Sound generator.
3. Voltage discharge testing — (a) Voltage spark, (b) Colour change.
4. Pressure leak testing — (a) Hydrostatic, (b) Pneumatic.
5. Ionization — (a) Photo-ionization, (b) Flame ionization
6. Conductivity — (a) Thermal conductivity, (b) Solid-state
7. Radiation absorption — (a) Infrared, (b) Ultraviolet, (c) Laser
8. Chemical-based — (a) Chemical penetrant, (b) Chemical gas tracer (Colorimetric)
9. Halogen detector — (a) Halide torch, (b) Electron capture, (c) Halogen diode
10. Pressure change measurement — (a) Absolute, (b) Reference, (c) Pressure rise, (d) Flow, (e) Pressure decay, (f) Volumetric
11. Mass-spectrometer — (a) Helium or argon leak detector, (b) Residual gas analyzer
12. Radio isotope.

Leak Testing, Level I — Practicals: (14 h)

a) Equipment familiarization,
b) Calibration,
c) Techniques specific application examples,
d) Interpretation of test results, and
e) Recording of test results

Inspection Method : Leak Testing
Level II

Subject 1	General Knowledge	4 h

1.1 Basic principles of NDT, Definitions, Methodology of applications, Areas of application of common methods, Range and limitations of common methods.

1.2 Materials and defects, Structure of metals and alloys, Physical and mechanical properties of metallic materials, Discontinuities and defects in metallic materials.

1.3 Processing defects, primary processes and related defects, Manufacturing processes and related defects.

1.4 Materials in service, Behaviour of materials in service, Service Conditions leading to defects and failures – (a) Corrosion, (b) Fatigue, (c) Wear, (d) Overload, (e) Brittle fracture, Concepts of rupture development in metals.

1.5 Quality and standardization, Definition of quality, quality, control, standardization. Development of a quality system, Examination, testing and inspection, Standards, Codes, Specifications and procedures, Reports, records and protocols.

Subject 2 — Physical Principles in Leak Testing — 2 h

2.1 Physical Quantities — Fundamental units, volume and pressure, time and temperature, absolute value, standard *versus* atmospheric conditions, leakage rates.

2.2 Structure of matter — Atomic theory, ionization and ion pairs, states of matter, molecular structure, diatomic and monatomic molecules, molecular weight.

2.3. Gas principles and laws — Brownian movement, mean free path, pressure and temperature effects of gases, Pascal's law of pressure, Charle's and Boyle's gas laws, ideal gas law, Dalton's law of partial pressure, vapour pressure and effects in vacuum.

2.4 Gas properties — Kinetic theory of gases, Graham law of diffusion, Stratification, Avogadro's principle, gas law relationship, general ideal gas law, gas mixture and concentration, Gas velocity, density and viscosity.

Subject 3 — Principles of Gas Flow — 3 h

3.1 Standard leaks — Capillary, permeation.

3.2 Modes of gas flow — Molecular and viscous, transitional, laminar, turbulent and sonic.

3.3 Factors affecting gas flow.

3.4 Geometry of leakage path — Mean free flow of liquid, clogging and check valve effects, irregular aperture size, leak rate *versus* cross section of flow, temperature and atmospheric conditions, velocity gradient *versus* viscosity, Reynolds number *versus* Knudsen number.

Subject 4 — Pressure Technology — 3 h

4.1 Properties of a fluid — What is a fluid, liquid *versus* gas, compressibility, partial and vapour pressure, critical pressure and temperature, viscosity of a liquid, surface tension and capillarity of its liquid.

4.2 Gas properties — Review of gas properties, perfect/ideal gas, pressure and temperature effects on gases, viscosity of a gas, gas flow modes, gas flow conductance, dynamic flow measurements, factors affecting gas flow.

4.3 Pressurization — Pressure measurements, types of pressure gages — (a) Bourdon or diaphragm, (b) Manometers, pressure control and procedure, mixing of gases, tracer gases and concentration, pressure hold time, pressure *versus* sensitivity, gage calibration — (a) Working range, (b) Frequency, (c) Master gage *versus* dead-weight tester.

4.4 Leak testing back ground/noise variables — Atmospheric changes, liquid/air temperature correction, vapour pressure (evaporation/condensation), Vapour/moisture pockets, geometry/volume changes, surface/internal vibration waves.

4.5 Detector/instrument performance variables — Instrument calibration variables, Limits of accuracy, Intrinsic and inherent safety performance, Protection for electromagnetic interference, radio frequency interference, shock, etc., Flooding, poisoning, contamination.

4.6 Measurement and data documentation — Experimental, simulation and/or preliminary testing, analysis of background/noise variables, analysis of leakage indications/signals, validation and error analysis, interpretation and evaluation of results, documentation of data and test results.

Subject 5 — Vacuum Technology — 3 h

5.1 Nature of vacuum — Vacuum terminology, degrees of vacuum, mean free path in a vacuum, gas flow in a vacuum.

5.2 Vacuum measurement — Pressure units in a vacuum, absolute *versus* gage pressure, mechanical gages : (a) Bourdon *or* diaphragm, (b) Manometer (V-tube *or* McLeod), (c) Capacitance manometer, Electrical gages : (a) Thermal conductivity, (b) Ionization, Gage calibration — full range.

5.3 Vacuum pumps — Types, Mechanical pumps : (a) Reciprocating *versus* rotary, (b) turbo molecular, drag pumps, Non-mechanical pumps : (a) Fluid entrainment or diffusion (b) Condensation *or* sorption.

5.4 Pump oils, pumping speed and pump-down time.

5.5 Vacuum materials — out gassing — vapour pressure, elastomers, gaskets, O-rings metals, metal alloys, and nonmetals, carbon steel *versus* stainless steel, aluminium, copper, nickel, and all, Non-metals : (a) Glass, ceramics (b) Plastics, Tygon™, etc. joint design : (a) Sealed joint, (b) Welded/brazed joint, (c) Mechanical joint, vacuum greases and sealing materials, tracer gas permeation through materials.

5.6 Design of a vacuum system — Production of a vacuum, removal of gas molecules gas quantity or throughput, conductance, stages of vacuum pumping, various vacuum pumps, various traps and baffles, Pumping stages or sequences, Vacuum valve location, vacuum valve design and seat leakage, isolation and protection, Automatic *versus* manual, Venting.

5.7 Maintenance and cleanliness — Maintenance of vacuum equipment, under constant vacuum, dry gas (nitrogen), routing oil changes, system cleanliness, initial cleanliness, cleaning procedures and effects on leak location and measurement, continued cleanliness.

5.8 Analysis and documentation — Analysis of outgassing and background contamination, instrument/system calibration, analysis of leakage indications/signals, interpretation and evaluation, documentation of calibration and test results.

Subject 6 **Leak Test Selection Course and Methods** **12 h**

6.1 Basic categories of leak testing — Leak location, leakage measurement, leakage monitoring.

6.2 Types of leak testing methods — Basic principles, Different techniques, Applications for different types of components, Procedure and Specifications, sensitivity, Calibration etc. for (a) Pressure Change/measurement test, (b) Bubble emission test, (c) Halogen Test and (d) Mass Spectrometer Leak Detection Test etc.

6.3 Basic techniques — Pressurization or evacuation, sealed unit with or without tracer gases, probing or visual leak location, tracer or detector probing, accumulation techniques.

Subject 7 **Codes and Standards** **2 h**

7.1 Codes, Standards and Specifications.

7.2 Procedures.

Subject 8 **Interpretation/Evaluation and Procedure** **3 h**

8.1 Basic techniques and/or units — Leak location — measurement/monitoring, Visual and other sensing devices, various techniques.

8.2 Test materials and equipment effects — Materials, gases/fluids used, Control devices and responses, Instrumentation/gages used, Range and calibration.

8.3 Effects of temperature and other atmospheric conditions.

8.4 Calibration for testing.

8.5 Probing/scanning or measurement monitoring.

8.6 Leak interpretation evaluation.

8.7 Acceptance and rejection criteria.

Subject 9	**Safety and Health**	**2 h**

9.1 Safety considerations — Personnel and public, Product serviceability, Test validity, Safe work practices.

9.2 Safety precautions — Explosives/implosives hazards, Flammability, Ignitability, Combustibility hazards, Toxicity and asphyxiation hazards, leaning and electrical hazards.

9.3 Pressure precautions — Pressure Test *versus* Proof test, Preliminary leak testing, Pressurization check, Design limitation, Equipment and set-up

9.4 Safety devices — Pressure control valves and regulators, Pressure relief valves and vents, flow rate of regulator and relief valves.

9.5 Hazardous and tracer gas safety — Combustible gas detection and safety, Toxic gas detection and safety, Oxygen — deficiency detectors, Radioisotope detection.

9.6 Types of Monitoring Equipment — Area monitors, Personnel monitors, Leak — locating devices.

9.7 Safety Regulations — State and federal regulations, Safety codes/standards, Hazardous gas standards, Radiation requirements.

Leak Testing, Level II — Practical (10 h)

a) Familiarization of equipments,
b) Pressure change test — Pressure and vac. applications,
c) Halogen test — Typical applications on various equipments,
d) Bubble leak test — Soap bubble test,
  1) Vacuum box soap bubble test, and
  2) Immersion test.
e) Mass spectrometer leak testing — Detector probe test,
  1) Tracer probe test,
  2) Pressure vacuum combinations, and
  3) Leak testing of sealed components, etc.
f) Procedure interpretation and understanding.

Inspection Method : Leak Testing
Level III

Subject 1	**General Knowledge (covered in Basic)**	

Subject 2	**Physical Principles**	**2 h**

2.1 Fundamental units — Volume and pressure, time and temperature, absolute values, standard *versus* atmospheric conditions, leakage rates.

2.2 Structure of matter — Atomic theory, Ionization and ion pairs, States of matter, Molecular structure, Diatomic and monatomic molecules, Molecular weight.

2.3 Gas principles and laws — Brownian movement, mean free path, pressure and temperature effects of gases, Pascal's law of pressure, Charle's and Boyle's gas laws, Ideal gas law, Dalton's law of partial pressure, vapour pressure and effects in vacuum.

2.4 Gas properties — Kinetic theory of gases, Graham law of diffusion, Stratification, Avogadro's principle, gas law relationship, general ideal gas law, gas mixture and concentration, Gas velocity, density and viscosity

Subject 3	**Principles of Gas Flow**	**4 h**

3.1 Standard leaks — Capillary, permeation.

3.2 Modes of gas flow — Molecular and viscous, Transitional, Laminar, turbulent and sonic.

3.3 Factors affecting gas flow.

3.4 Geometry of leakage path — mean free flow of liquid, clogging and check valve effects, irregular aperture size, leak rate *versus* cross section of flow, temperature and atmospheric conditions, velocity gradient *versus* viscosity, Reynolds number *versus* Knudsen number.

3.5 Proper selection of LT as method of choice — Differences between LT and other methods, Complementary roles of LT and other methods, Potential for conflicting results between methods, factors that quality/disqualify the use of LT.

Subject 4 Equipment/Material 8 h

4.1 Leak testing standards — Capillary or permeation, system *versus* instrument calibration, inaccuracy of calibration

4.2 Detector/instrument performance factors — Design and use, accuracy and precision, linearity (straight/logarithmic scale), calibration and frequency, response and recovery time.

4.3 Vacuum pumps — Mechanical pumps (positive displacement) (a) Oil-sealed rotary pumps : (1) Construction (2) Operation (3) Pump fluid (4) Difficulties with rotary pumps (5) Care of rotary pumps (b) Vapour (diffusion) pumps : (1) Construction (2) Operation (3) Pump fluid (4) Diagnosis of diffusion pump troubles (c) Sublimation pumps (getter pumps) (d) Ion pumps (e) Turbomolecular pumps (f) Absorption pumps (g) Cyro pumps

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Subject 5 Testing practices and techniques 8 h

5.1 Bubble testing — Solutions, solution applicators, vacuum boxes.

5.2 Absolute pressure testing equipment — Pressure measuring instruments, temperature measuring instruments, Dew point measuring instruments, accuracy of equipment, calibration of equipment, reference panel instruments, reference system installation and testing.

5.3 Absolute pressure hold testing of containers — Equation for determining pressure change, temperature measuring.

5.4 Absolute pressure leakage rate testing of containers — equation(s) for determining percent loss, Positioning of temperature and dew point sensors for mean sampling accuracy, analysis of temperature and dew point data.

5.5 Analysis of data for determination of accurate results.

5.6 Halogen testing equipment — Leak detector control unit, gun detectors, standard leaks, refrigerant tracer gases.

5.7 Helium mass spectrometer testing equipment, Mechanical vacuum pump systems, Cryogenic pumps, Diffusion pumps, Vacuum gauges, Vacuum hose, Vacuum valves, Standard leaks, Vacuum sealing compounds, Vacuum connectors, Detector“Sniffer” probes, tracer probes.

Subject 6 Techniques/Calibration 6 h

6.1 Bubble testing techniques — Vacuum box testing, Pipe, nozzle and pad plate testing, Vessel testing, weather effects and lighting.

6.2 Halogen diode detector leak test — Calibration of detectors for testing, standard leak settings, Halogen mixture percentages, Detection sensitivity *versus* test sensitivity, halogen detector probe “sniffer” testing techniques and practices, detector probe “sniffer” speed, Halogen background, Effects of heat on refrigerant R-12, Halogen leak detector operation and servicing, Operation of the probe, Replacing the sensing element, Cleaning the sensing element

6.3 Mass spectrometer leak testing, terminology related to mass spectrometer testing, Helium mass spectrometer — Operation, Calibration, Maintenance, Helium mass spectrometer pressure testing — detector probe “sniffer” techniques, mixture percentage, Pressure differential techniques, Bagging-accumulation techniques, Calibration helium mass spectrometer for “sniffer” testing.

Helium mass spectrometer vacuum testing by dynamic method — (a) Tracer probing (b) Bagging or hooding (c) System calibration (d) Helium mixture (e) Calculation of leakage rate.

Helium mass spectrometer vacuum testing by static method — (a) Static equation (b) System calibration (c) Helium mixture (d) System pressure (e) Calculation of leakage rate.

Subject 7	Safety and Health	2 h

7.1 Safety considerations — Personnel and the public, Product serviceability, Test validity, Safe work practices

7.2 Safety precautions — Explosive/implosive hazards, Flammability, ignitibility, combustibility hazards, Toxicity and asphyxiation hazards, Cleaning and electrical hazards.

7.3 Pressure precautions — Pressure test *versus* Proof test, Preliminary leak test, Pressurization check, Design limitations, Equipment and set-up.

7.4 Safety devices — Pressure control valves and regulators, Pressure relief valves and vents, flow rate of regulator and relief valves.

7.5 Hazardous and tracer gas safety — Combustible gas detection and safety, Toxic gas detection and safety, Oxygen-deficiency detectors, Radioisotope detection.

7.6 Types of monitoring equipment — Area monitors, Personnel monitors, Leak-locating devices.

7.7 Safety — Safety codes/standards, Hazardous gas standards, Nuclear Regulatory Commission (NRC) radiation requirements.

Subject 8	Codes and Standards	2 h

8.1 Applicable Codes, Standards and Specifications.

8.2 Leak testing procedures — Basic categories and techniques, leak location *versus* leakage measurement. Pressurization or evacuation, Sealed units with or without tracer gas, nits accessible from one or both sides, Systems at, above, or below atmospheric pressure.

8.3 Leak testing specifications — Design *versus* working conditions, Pressures and temperature control, Types of leak testing methods, Sensitivity of leak testing methods, Test method and sensitivity needed, preparation of a leak testing specification procedures.

Subject 9	Interpretation/Evaluation and Procedure	4 h

9.1 Basic techniques and/or units — Leak location — measurement/monitoring, Visual and other sensing devices, various techniques.

9.2 Test materials and equipment effects — Materials, gases/fluids used, Control devices and responses, Instrumentation/gages used, Range and calibration.

9.3 Effects of temperature and other atmospheric conditions.

9.4 Calibration for testing.

9.5 Probing/Scanning or measurement monitoring.

9.6 Leak interpretation evaluation.

9.7 Acceptance and rejection criteria.

Subject 10	Quality Assurance and Standardization	2 h

10.1 Quality assurance; basic principles for the application of quality assurance — Organization of quality assurance — Quality manual, quality control; auditing of quality. Management and control of quality assurance documentation, quality control of testing, Reports on testing, documentation system.

10.2 Standardization — Definition of standardization, Principles of standard writing, Standards, Codes, Specifications and procedures, their uses — Reports and protocols.

Subject 11 **Organization and Administration of NDT Safety** **2 h**

11.1 Organization and administration of NDT Safety (a) Implementation of industrial safety in facilities and their operation, (b) Hazards of using toxic and inflammable materials, (c) Materials, accessories and equipment for the protection of per and facilities.

11.2 Organization — Equipment for work under way, logistic provision, testing on production lines, Flow of materials, Work shifts, Maintenance of equipment and facilities.

11.3 Costs — Investment in equipment, Direct and indirect staff costs, Calculation and analysis of costs and profitability.

11.4 Equipment selection and facility design — Operation procedures and record keeping.

Subject 12 **Qualification and Certification of NDT Personnel** **1 h**

12.1 Qualification and certification of personnel for NDT — National standards for the qualification and certification of personnel — Training of personnel for NDT — Organization of courses and training in NDT methods — Code of ethics.

ANNEX B

(Foreword)

JOB SPECIFIC SECTORS

Eddy Current and Electromagnetic Sorting of Materials

Subject 1 **Basic Principles of Eddy Currents and Electromagnetism**

1.1 Electricity — Direct current, amperage, voltage ohm's law and resistance, conductivity and resistivity, alternating current.

1.2 Electromagnetic induction — Field generated by a current, Field/induction relationship, Effect of fill factor, Effect of frequency, Influence of magnetic field.

1.3 Magnetism — Magnetic data, Induction and Magnetic fields, magnetic permeability, Coercive force, saturation magnetism, iron magnetization, induced magnetic flux, lines of force and force fields.

1.4 Electromagnetism, Magnetic field produced by a current, inductive current — eddy current, skin effect, effect of test frequency, reactance (field produced by eddy current).

Subject 2 **Theory of Eddy Currents**

2.1 Distribution of eddy currents, Plane conductors, Depth of standard penetration, Defect reaction according to its position.

2.2 Cylindrical bars — Depth of standard penetration, Defect reaction according to its position.

2.3 Tubes — Depth of standard penetration, Defect reaction according to its position.

Subject 3 **Characteristics of Eddy Current and Electromagnetic Sorting Probes and Coils**

3.1 Induction and reception functions — Absolute and differential measure, Type of probes, encircling, internal, surface, hybrid field from an empty coil.

3.2 Effect of coupling — EC distribution related to coil position.

Subject 4 **Eddy Current Equipment**

4.1 Working principles — Transmission, reception, data presentation.

4.2 Equipment controls — oscillator — frequency control, Magnetizing current control, Energising devices and measurement, Balancing the system, Sensitivity, Amplifier, filter, modulation/demodulation, Phase rotation.

4.3 CRT display — Ellipse, A-scan vector point, analogue display – digital/meter, Gain control.

Subject 5 **Properties of Materials**

5.1 Physical properties — Ferromagnetic and non-ferromagnetic materials — Electrical conductivity — Effect of chemical analysis, temperature, hardness, grain structure, texture, cold work, structure, Magnetic permeability — effect of chemical analysis, temperature, hardness, grain structure, texture, cold work, structure.

Subject 6 **Influences of Various Parameters on Eddy Current Measurement**

6.1 Defect position and orientation, EC path, penetration depth, zone of probe action, material temperature, structure and geometry of test part.

6.2 Choice of frequency, phase discrimination, noise filtering, magnetic saturation coupling influence, vibrations, centering, fill factor, sensitivity, compensation.

6.3 Relative speed, Testing frequencies according to speed.

Eddy Current and Electromagnetic Testing of Tubular Products During Manufacture

Subject 1 Basic Principles of Eddy Currents and Electromagnetism

1.1 Electricity — Direct current — amperage, voltage ohms law and resistance, conductivity and resistivity, Alternating current.

1.2 Electromagnetic induction — Field generated by a current field/induction relationship, Effect of fill factor, Effect of frequency, Influence of magnetic field.

1.3 Magnetism — Magnetic data, Induction and magnetic fields, Magnetic permeability, Coercive force, saturation magnets, Iron magnetisation, Induced magnetic flux, Lines of force and force fields.

1.4 Electromagnetism — Magnetic field produced by a current — Inductive current — eddy current, Skin effect, effect of test frequency.

1.5 Reactance (field produced by eddy current).

Subject 2 Theory of Eddy Currents

2.1 Distribution of eddy currents in tubular products, Depth of standard penetration, Defect reaction according to its position

Subject 3 Characteristics of Eddy Current Coils

3.1 Induction and reception functions, differential mode, encircling coils, field from an empty coil.

3.2 Effect of coupling, Eddy current distribution related to coil position.

Subject 4 Eddy Current Equipment

4.1 Working principles, transmission, reception, data presentation.

4.2 Equipment controls, oscillator — Frequency control, magnetizing current control, Energising devices and measurement, balancing the system, Sensitivity, Amplifier, filter, modulation/demodulation, Phase rotation.

4.3 CRT display — ellipse, A-scan vector point, analogue/digital display, Gain control.

Subject 5 Properties of Materials

5.1 Physical properties, Ferromagnetic and non-ferromagnetic materials, Electrical conductivity and magnetic permeability — effect of temperature, structure, cold work.

Subject 6 Influences of Various Parameters on Eddy Current Measurement

6.1 Defect position and orientation, eddy current path, penetration depth, zone of probe action material temperature, structure and geometry of test part.

6.2 Choice of frequency, phase discrimination, noise filtering, magnetic saturation, Coupling influence, Vibrations, centering, fill factor, sensitivity, compensation, Relative speed, Testing frequencies according to speed.

Radiographic Film Interpretation

Subject 1	**Basic Principles of Radiographic Testing**

1.1 Generation of X-ray and Υ-radiation, Radiation sources, Properties of the radiation.

1.2 Attenuation of radiation, Interaction of radiation with matter, Scattering and absorption.

1.3 Film imaging, Characteristics of film systems.

1.4 Film processing, Procedures, Processing faults, and articrafts.

1.5 Film viewing conditions, Environmental conditions, Ambient light levels, Viewer brightness, Physical acclimatisation.

1.6 Radiographic image quality, Radiographic contrast, Film contrast, Subject contrast, Image sharpness, Exposure arrangements, Geometric unsharpness, Inherent unsharpness, Image quality indicators, Sensitivity determination.

Subject 2	**Applicable Codes, Standards and Specifications**

2.1 Exposure arrangements (single and double walled), Radiation energy and source, Geometrical condition, film systems, film density, number of exposures, protection against scattered radiation, image quality indicators, test report, exceptions and agreements, limits of test procedure, limits in respect to the detectability of irregularities, classification of discontinuities.

2.2 Product technology, Manufacturing and fabrication processes, causes and origin of discontinuities resulting from the production process and in-service degradation, Position and orientation of discontinuities.

Subject 3	**Evaluations of Radiographs**

3.1 Viewing conditions, confirmation of the exposure technique, recognising and reporting of discontinuities, according to codes, specifications and standards, analyse and interpretation of test results, test report.

Normal Beam Ultrasonic Testing of Plate Materials During Manufacture

Subject 1	**Basic Principles of Accoustics**

1.1 Nature of sound waves, Modes of sound wave generation, Velocity, frequency and wavelength of sound waves, Attenuation of sound waves, Accoustic impedance, Reflection, Refraction and mode conversion, Fresnel and Fraunhofer effects.

Subject 2	**Equipment**

2.1 Basic and pulse-echo instrumentation (A, B and C scan and computerised systems), Electronics; time base, pulser, receiver, and various monitor displays, Control functions, Calibration, Basic instrument calibration, Calibration blocks, Transducer operation and theory, Piezoelectric effect, Types of crystals, Frequency (crystal thickness relationship), Near and far fields, Beam spread, Construction; materials and shapes, Types, Beam intensity characteristics, Sensitivity resolution and damping, Mechanical vibration into test material, Couplants, Purpose and principles, Materials and efficiency.

Subject 3	**Basic Testing Methods**

3.1 Contact, Immersion, Multiple transducer, Transducer in water, Water column, wheels etc, Submerged test part, Sound beam part — transducer to part, Focussed transducers, Comparison of contact and immersion techniques.

Subject 4	**Calibration (Electronic and Functional)**

4.1 Equipment, Monitor displays, Recorders, Alarms, Automated and semi-automated systems, Distance amplitude correction (DAC/DGS), Transducers, Calibration of equipment electronics, Variable effects, Transmission accuracy, Calibration requirements, Calibration reflectors, Inspection calibration, Comparison with reference blocks, Pulse echo variables, Reference for planned tests, Transmission factors, Transducer, Couplants, Materials.

Subject 5 **Straight Beam Examination to Specific Procedures**

5.1 Selection of parameters, Test standards, Evaluation of results, Test reports.

Subject 6 **Evaluation of Product Forms**

6.1 Ingots, Process review, Types and origins of discontinuities, Plate, Rolling process, Types and origins of discontinuities to ultrasound, Applicable Codes, Standards and Specifications.

Subject 7 **Discontinuity Detection**

7.1 Sensitivity to reflections, size, type, and locations of discontinuities, Techniques used in detection, Resolution, Standard reference comparisons, Probability of type of discontinuity, Effects of ultrasonic frequency, Damping effects, Determination of discontinuity size, Monitor displays, Transducer movement *versus* display, Signal patterns, Location of discontinuity, Amplitude and linear time, Search technique.

Subject 8 **Evaluation**

8.1 Comparison procedures, Standards and references, Amplitude, area and distance, Object appraisal, History of part, Existing and applicable code interpretation, Type of discontinuity and location.

Ultrasonic Thickness Testing

Subject 1 **Properties and Behaviour of Ultrasound**

1.1 Frequency, velocity, wavelength, amplitude, Continuous and pulsed waves, Modes of vibrations, Acoustic impedance pressure, energy, intensity, Reflection, refraction and mode conversion, Diffraction, dispersion and attenuation, Generation of ultrasound, Piezoelectricity and types of crystals, Construction of ultrasonic search units, characteristics of search units-frequency — crystal thickness relationship, conversion efficiencies of various crystals, Damping and resolutions, Beam intensity characteristics — near field, far field divergence, Normal and angle probes, Flat and contoured probes, Flat and contoured probed, Single crystal and twin crystals probes, Care of search units, ultrasonic Testing Equipment, Description of basic pulse-echo instrument, Time-base (synchroniser) circuit, Pulser circuits, Receiver or echo-amplifier circuit, A-scan display circuit, Horizontal linearity — Digital instruments, Care of equipment, Types of couplants, desirable characteristics, Probe selection — Single crystal probes, Single crystal probes with spacers, Twin crystal probes.

Subject 2 **Testing Methods**

2.1 Contact testing — Straight beam, Calibration, Types and uses of calibration blocks for thickness testing, Secondary calibration, Test application, Selection of test parameters, Frequency, Probe type, size and shape, Methods of measurement — Single spot, Double spot, Grid.

2.2 Interpretation of results, Recording and reporting, Job records, Routine reports, Codes and standards, Use of correction factors and charts, Order of accuracy, Variables affecting test results, Instrument performance variables, Transducer performance variables, Inspected part variables, Entry surface conditions, Part size and geometry.

2.3 Metallurgical structure — Material temperature, Surface coatings, Corrosion.

2.4 Abnormal values, nil readout, half anticipated thickness readout, Double anticipated thickness readout.

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